

For Reference

NOT TO BE TAKEN FROM THIS ROOM

For Reference

NOT TO BE TAKEN FROM THIS ROOM

Ex libris
UNIVERSITATIS
ALBERTAENSIS





Digitized by the Internet Archive
in 2019 with funding from
University of Alberta Libraries

<https://archive.org/details/Staples1967>

THE UNIVERSITY OF ALBERTA

THE EFFECT OF CIRCUIT TRAINING ON
STRENGTH AND CARDIOVASCULAR ENDURANCE

by

R. BRIAN STAPLES

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

FACULTY OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

APRIL, 1967

APPROVAL SHEET

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies, a thesis entitled "The Effect of Circuit Training on Strength and Cardiovascular Endurance" submitted by Richard Brian Staples in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

The purpose of this study was to investigate the effects of a program of Circuit Training on selected strength and cardiovascular measures. The program was administered over a ten week period, five days per week for a duration of ten to twelve minutes per day in which from two to three circuits per individual were performed. Grade Eight and Grade Nine boys (N=60) and girls (N=38) were used as subjects. Cardiovascular endurance was measured by the Astrand-Ryhmung (10) Predicted Maximal Oxygen Intake Test with values given in liters per minute. Muscular strength was measured by cable tensiometer and grip dynamometer techniques after the methods used by Howell, Loiselle and Lucas (53). Each individual's strength scores were summed to give a single strength index in pounds.

Boys and girls were treated separately on both of the indices employed and each sex had an experimental group which performed Circuit Training and a control group which performed Structured Play in lieu of Circuit Training as part of the daily physical education class period.

The following conclusions appear to be reasonable within the limitations of the samples investigated, the cardiovascular and strength measurements employed, the types and performance of the Circuit Training employed and the statistical treatment used:

1. Circuit Training influenced the boys' experimental group to change in a significantly different way than the

boys' control group in terms of predicted maximal oxygen consumption. The experimental group mean increased while the control group mean decreased.

2. Circuit Training influenced the girls' experimental group to change in a significantly different way than the girls' control group in terms of predicted maximal oxygen consumption. The experimental group mean increased while the control group mean decreased.

3. The boys' experimental group did not change in a significantly different way than the boys' control group in terms of summed strength values. The means of both groups increased, but the mean of the experimental group increased more than the mean of the control group.

4. Circuit Training influenced the girls' experimental group to change in a significantly different way than the girls' control group in terms of summed strength values. The means of both groups increased, but the mean of the experimental group increased more than the mean of the control group.

5. Significant Trials effects were achieved in comparisons involving boys' groups as well as girls' groups on summed strength values and boys' groups on predicted maximal oxygen consumption values. A significant Trials effect indicates that the overall mean of values of a control and experimental group considered after the experiment is significantly different from the overall mean of values of the same groups considered before the experiment. In each case, experimental groups had final mean values that were higher than respective

control group means.

6. No significant Groups effects were achieved by either sex on either variable. An insignificant Groups effect signifies that the overall mean of the experimental group considered before and after the experiment is not significantly different from the overall mean of the control group considered before and after the experiment.

Differences were considered significant at the 0.05 level of confidence.

A C K N O W L E D G M E N T

I wish to acknowledge the assistance given in the preparation of this thesis by my faculty committee members, Dr. M. Gulutsan and Dr. M. L. Howell. I especially appreciated the advice given, and the manner in which that advice was given, by Gerry Glassford, committee chairman.

This study could not have been carried out without the approval and co-operation of the Devon County Council, school administration and staff. I wish to express my appreciation of their assistance and tolerance.

I am indebted to Irvin Servold and John Cameron for their expert assistance in conducting much of the testing involved. I also wish to thank all of the students of the Devon High School who helped with the testing.

Finally, I wish to dedicate this work to my wife Marjorie and children Christopher, David and Lisa in the hope that in the future we may be able to devote the time to each other that was not possible because of the commitment required herein.

TABLE OF CONTENTS

CHAPTER	PAGE
I STATEMENT OF THE PROBLEM.....	1
Introduction.....	1
The Problem.....	3
Justification of the Study.....	4
Limitations of the Study.....	6
Definition of Terms.....	6
II REVIEW OF THE LITERATURE.....	11
Literature Related to Circuit Training.....	11
Summary of Literature Reviewed on Circuit Training.....	18
Literature on the Astrand-Ryhming Test for the Prediction of Maximal Oxygen Intake..	18
Validity and Reliability of the Astrand- Ryhming Nomogram.....	19
Factors that Influence Maximal and Submaximal Oxygen Intake.....	25
Summary of Literature Reviewed on the Astrand-Ryhming Nomogram.....	30
Literature Related to the Testing of Strength...	32
Literature Related to Strength Characteristics of School Aged Boys and Girls.....	35
Summary of Literature Reviewed on Strength.....	37
III METHODS AND PROCEDURE.....	38
The Circuits.....	38
Class Routine and the Set Piece Method.....	39
Motivation on the Circuit.....	40

Design of the Study.....	41
The Astrand-Ryhming Test for the Prediction of Maximal Oxygen Intake.....	44
The Howell-Loiselle-Lucas Strength Measuring Techniques.....	46
Description of the Strength Tests.....	48
Equipment Calibration.....	51
Statistical Treatment.....	52
IV RESULTS AND DISCUSSION.....	53
Results of the Effects on Boys of Circuit Training in Terms of Oxygen Consumption.....	54
Results of Effects on Girls of Circuit Training in Terms of Oxygen Consumption.....	57
Results of Effects on Boys of Circuit Training in Terms of Summed Strength.....	59
Results of Effects on Girls of Circuit Training in Terms of Summed Strength.....	61
Summary of Results for Boys and Girls in Terms of Oxygen and Strength.....	62
Discussion of Predicted Maximal Oxygen Consumption Results.....	64
Discussion of Summed Strength Results.....	66
Discussion of Motivation on the Circuit.....	68
Discussion of Results of this Study in Comparison to Other Circuit Training Studies.....	69
V SUMMARY AND CONCLUSIONS.....	72

Summary.....	72
Conclusions.....	75
Recommendations.....	76
BIBLIOGRAPHY.....	78
APPENDICES	
A. STATISTICAL TREATMENT.....	
B. OXYGEN NOMOGRAM DATA SHEET	
STRENGTH DATA SHEET.....	
C. RAW DATA.....	
D. CIRCUIT ADMINISTRATION.....	
E. CIRCUIT TEST SCORE SHEET.....	

LIST OF TABLES

TABLE		PAGE
I	TEST RETEST RELIABILITY COEFFICIENTS FOR FEMALES.....	33
II	TEST RETEST RELIABILITY COEFFICIENTS FOR MALES.....	34
III	TEST RETEST RELIABILITY COEFFICIENTS.....	35
IV	ANALYSIS OF VARIANCE -- BOYS PREDICTED MAXIMAL OXYGEN VALUES.....	55
V	ANALYSIS OF VARIANCE -- GIRLS PREDICTED MAXIMAL OXYGEN VALUES.....	58
VI	ANALYSIS OF VARIANCE -- BOYS SUMMED STRENGTH VALUES.....	60
VII	ANALYSIS OF VARIANCE -- GIRLS SUMMED STRENGTH VALUES.....	63
VIII	DATA FOR t TEST AND ANALYSIS OF VARIANCE OF GIRLS OXYGEN VALUES.....	APPENDIX A

LIST OF FIGURES

FIGURE	PAGE
1	COMPARISON OF MEAN OXYGEN VALUES FOR BOYS..... 55
2	COMPARISON OF MEAN OXYGEN VALUES FOR GIRLS..... 58
3	COMPARISON OF MEAN STRENGTH VALUES FOR BOYS..... 60
4	COMPARISON OF MEAN STRENGTH VALUES FOR GIRLS..... 63
5	CIRCUIT LAYOUTS..... Appendix D
6	CIRCUIT EXERCISES..... Appendix D

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction.

The enactment of Bill C-131 (17) (An Act to Encourage Fitness and Amateur Sport) by the Federal Government of Canada serves as convincing evidence of the fact that the political leaders of our country are somewhat concerned about the level of physical fitness of the people of Canada. The provision of five million dollars in any one fiscal year as may be required for the purposes of this act serves to verify this concern.

The American Association for Health, Physical Education and Recreation may help to bring to light the reason for this concern in the following statement (5):

Although man's need for survival has changed, his biological design has not. He is still meant to be an active, not a sedentary individual. Modern man has a critical choice, either he includes in his life vigorous activities or suffers losses. If he chooses to remain fit, he must elect those activities and practices that lead to this end.

A Canadian publication, the 5BX Plan of the R.C.A.F. (74) relates the situation to Canada as follows:

Mechanization, automation and worksaving devices to make life easier are depriving us of desirable physical activity. Canadians, as a result, are in danger of deteriorating physically despite the high standard of living.

A conflict of opinions is possible over the direction that physical education should take in the schools. Should physical educators concentrate on physical fitness, or should broader objectives be striven for, among which is included

physical fitness? This dilemma is intensified by the current public and governmental emphasis on physical fitness and the limited time and facilities given physical education in some school situations.

A review (72:45) of over thirty-five courses of study for public schools, representative of the United States and Canada, provides a resume of opinions concerning the objectives of physical education. To indicate the broad scope of physical education, four to six objectives under each of three main headings; Physical Development, Mental Development and Social Development, for a total of fifteen specific objectives can be listed according to this review.

Other authorities (28, 81, 95) emphasize the fitness objective of physical education.

In the school situation with limited time available, if skills for use in leisure time, positive attitudes, social cooperation, and knowledge of physical education are emphasized, the student may not know what it is to be physically fit and, therefore, not value that state. On the other hand, if physical fitness activities are the major concern of the teacher, where will the student learn to become proficient in and predisposed to wholesome, vigorous leisure time activities, with their concomitant values?

Van Vliet, in his book Physical Education for Junior and Senior High Schools (90:4) summarized the reasons for, and gives direction toward, an answer to this dilemma:

Physiologists contend that secondary school students need

from one to two hours of big muscle activity each day for normal growth and development. Sociologists and psychologists emphasize the need for group experience and personal development. The physical education program, given enough time each day and reasonable facilities with proper supervision, can provide the best practical laboratory for the accomplishment of these recognized human requirements; and, further it provides knowledge, skill and enjoyment which can be extended into more wholesome use of leisure time.

The problem for the teacher of physical education is that of being able, in a manageable fashion, to use available facilities in applying educationally sound activities over sufficient time to achieve the variety of desirable goals.

The Problem.

The purpose of this study was to investigate the physiological effects of a program of Circuit Training. The program was administered over a ten week period, five days per week for a minimum of ten minutes or two circuits and a maximum of twelve minutes or three circuits daily. Effects were noted on the cardiovascular endurance and muscular strength of Grade Eight and Grade Nine boys and girls. Cardiovascular endurance was measured by the Astrand-Ryhming (10) predicted maximal oxygen intake test with values given in liters consumed per minute. Muscular strength was measured by cable tensiometer and grip dynamometer techniques after the methods used by Howell, Loiselle and Lucas (53). Strength scores were summed to give a single strength index for each subject.

Boys and girls were treated separately on both of the indices employed and each sex had an experimental group which performed Circuit Training and a control group which performed

Structured Play instead as part of the daily physical education class. The following hypotheses were tested.

The null hypotheses assert there will be no significant Groups, Trials, and Groups by Trials effects (36) achieved by groups of either sex on either of the indices employed over the course of the experiment. The alternate hypotheses assert there will be significant Groups, Trials, and Groups by Trials effects.

Justification of the Study.

There have been several articles describing aspects of Circuit Training (3, 4, 46, 47, 48, 49, 68) and several have described controlled experimentation and its effect on the human body (2, 4, 21, 51, 52, 67, 71, 84, 93). Only two articles have been found showing the effects of Circuit Training on school children (4, 21).

Circuit Training, as a method of achieving physical fitness, has many advantages that warrant its use in the school situation. Major considerations are that it provides for individual differences (50:12) within the class, and allows the pupil to work without direct supervision. Opportunity is provided the pupil to practice self direction and to take responsibility for his own actions. The teacher is permitted to plan for the conclusion of each session of fitness training at a specific time point in the class period. In addition, Circuit Training frees the teacher from direct active participation in conducting the fitness program, an important practical consideration for any teacher who may

have seven or eight classes arriving one after another daily. Circuit Training, then, appears to be educationally sound as a physical fitness method.

The number of high school physical education class periods offered per week varies in the province of Alberta. Situations exist in which one double period a week is given. Other situations differ, with from two to five separate sessions offered per week. A physical education class period may be from thirty-five to fifty-five minutes in length, but the basic period is forty minutes long.

The maximum amount of physical education offered is a daily class (five days a week) of forty minutes or the equivalent of two hundred minutes per week.

The way one divides up the class time available is, of course, a question of values. From the practical point of view, assuming one subscribes to all the goals of physical education, if one allows about ten minutes to be used for changes of costume, a shower, etc., and about twenty minutes for such things as theory, strategy, skills, practice of skills, play, etc., then only ten minutes are available for direct physical fitness training (some physical fitness benefits may accrue incidentally from the other forms of activity offered). It may be useful, then, to know whether or not a minimum of ten minutes of direct fitness training of an educationally sound nature, applied equally over the maximum number of sessions available, is, in fact, of any benefit.

Limitations of the Study.

1. The subjects were all medically fit boys and girls enrolled in Physical Education in Grades Eight and Nine at Devon High School, Devon, Alberta. General conclusions are limited because of the hypothetical nature of the population which the non-random sample represents.

2. Only two aspects of physical fitness were measured, cardiovascular endurance and muscular strength as represented by the indices given in the statement of the problem.

3. Only one specific program of Circuit Training involving a combination of three types of circuits was studied. There are many possible forms that Circuit Training may take.

4. Motivational influences unique to the conduct of the Circuit Training Program used limit the conclusions drawn.

5. The program was applied over a ten week time period.

6. The study was further limited by the nature of the statistical procedures that were utilized to analyze the data.

Definition of Terms.

Circuit Training. Circuit Training is a system of exercises arranged in the form of a circle or circuit in such a manner as to enable a large group of students to proceed from one exercise to another without undue local fatigue. Each student in the group performs at his or her own work capacity. "Progression on a circuit is measured, initially, by decreasing the time of performance, and secondly, by increasing loads or repetitions (50:12)."

Circuit Forms. Three forms of Circuit Training were employed and were designated Isotonic or Regular, Weight, and Endurance or Laps (Appendix D).

Isotonic Circuit. This form of Circuit Training involved a series of exercises in which the individual repeated specific body movements using his own body weight as a resistance. It was intended to develop both muscular strength and cardiovascular endurance.

Weight Circuit. This form of Circuit Training involved a series of exercises in which the individual repeated specific body movements using extraneous weights as a resistance. It was intended to develop muscular strength.

Endurance Circuit. This form of Circuit Training involved running laps around the gymnasium floor. It was intended to develop the cardiovascular endurance.

Circuit Station. A circuit station was a location where a designated exercise was performed a specified number of repetitions or within a desired time limit. The repetitions or desired time limits varied with each individual.

Circuit. Progression through a series of circuit stations constituted the performance of a circuit.

Circuit Training Session. The performance of two to three circuits at one training period constituted a Circuit Training Session.

Circuit Training Program. A repetition of daily Circuit Training Sessions, five times per week, over ten weeks constituted the Circuit Training Program used in this study. The intention of the Circuit Training Program was that each individual might achieve a physiological overload which stimulated the growth of both the cardiovascular system and selected skeletal muscle groups.

Short Circuiting. This term meant the process of failing to perform the circuit according to designed expectations, cheating on the circuit. This may be done by loitering on the circuit, "skipping" stations, doing fewer than required repetitions at each station, using improper form at each station, etc.

Structured Play. The practical application of an activity being learned in class, actual playing of volleyball, actual target shooting in archery or a game in basketball was the meaning of this term in this study. The activity was open to intermittent interruption by the teacher who may have wished to further teach the sport by using examples of play situations that had arisen in the course of the activity.

Cardiovascular Endurance. This term can also be referred to as cardiorespiratory endurance or circulatory endurance, and was considered to be a kind of physiological fitness demonstrated through the ability of the heart and lungs to adjust to prolonged physical exertion (32:105).

Muscular Strength. This was the capacity of a subject

to apply a recordable force to an instrument, through the use of an isometric contraction developed by one or more muscle groups of the body (53:4).

Astrand-Ryhming Predicted Maximal Oxygen Intake Test.

This was a submaximal bicycle ergometer test from which the maximal oxygen intake in liters of oxygen per minute (aerobic work capacity) of an individual was estimated from a nomogram. The subject pedalled the bicycle ergometer at a steady rate with a given resistance over a calculated time until a steady state was reached. The amount of work done was calculated in kilopond meters per minute and its relation to heart rate at steady state was compared on a nomogram to give the predicted maximal oxygen intake.

Aerobic Work Capacity. The maximal oxygen intake of an individual in liters of oxygen per minute in this study, was considered to be an individual's aerobic work capacity.

Steady State. A steady state occurs when the individual's organic functions have adapted to the work being performed. At this time oxygen intake is equal to the work being done. In this study, a steady state was considered to have been reached when pulse rates, measured at the ends of two consecutive minutes of pedalling the bicycle ergometer did not vary more than ± 5 beats per minute.

Kilopond Meter (Kpm.). One kilopond is the force acting on the mass of one kilogram at normal acceleration of

gravity (10). A kilopond meter is a kilopond acting over one meter.

Maximal Oxygen Intake. The maximal oxygen intake was the rate of oxygen consumption attained when the cardio-respiratory mechanisms could make no further adjustments to increasing work loads, i.e., oxygen intake remained constant or decreased even if the work load was being increased.

Summed Strength Score. The sum of the strength scores in pounds of selected muscle groups of the body was considered an individual's summed strength score. In this study, ten different strength measurements were made. These were, for both sides of the body: grip strength, elbow flexion, elbow extension, and knee extension. Leg lift and back lift were also tested and included in the summed total. Two measurements for each muscle group tested were made and the highest of the two was included in the summed total.

CHAPTER II

REVIEW OF THE LITERATURE

Literature Related to Circuit Training.

Circuit Training was developed at Leeds University in Great Britain by Morgan and Adamson (68). It is a method of progressive resistance fitness training geared to individual differences, but may be used by a group. It was initially developed for use at the university level but has since been adapted for use in secondary schools (50).

A series of different fitness activities are situated in circular pattern about the exercise area. Participants move from one activity to another, doing individually prescribed numbers of repetitions of an exercise at each stop. The series is performed three successive times, each identical performance being known as a circuit. The number of repetitions performed is calculated to achieve an overload of selected body muscular systems and/or the cardiovascular system by the end of the third circuit. The developers of Circuit Training have fully outlined the nature and methods of the system in their book entitled Circuit Training (68).

There are several different kinds of Circuit Training Programs. Any number or combination of exercises can be used. In analyzing the three methods of Circuit Training outlined by Morgan and Adamson (68) one finds:

1. "Individual Measurement Method." Each student does his own dose (number of executions or repetitions per circuit

station) in his own time. All students finish the circuit at different times.

2. "The Beginner's Dose and Progression Method." Each student does a given dosage in a given time. All students finish the circuit activity at the same time, but exact individual dosage is not performed, rather broader levels of difficulty are encountered as one progresses from an easier to a more difficult circuit.

3. "The Fixed Dose Method." Each student does a given dose in his own time. Students finish the circuit at different times.

Howell and Morford (50) presented an adaptation of the "Individual Measurement Method" that is probably better suited to a school class situation than any of the three listed. It allows all students to finish the circuit at the same time, thus permitting the teacher to plan for a definite time for the training, yet each student does an exact individual dose.

The fact that Circuit Training can provide an exact dosage for each student and thereby cater to individual differences within a class without drawing attention to the difference of individuals is probably one of its more important educational assets.

In this connection, Watt (92) was of the opinion that special attention should be given individuals who are deficient in basic fitness elements, if physical education is to contribute to the improvement of the physical fitness of our youth. He listed the following features of Circuit Training

that make it adaptable to developmental programs. Such qualities, in addition, give some indication as to the desirability of the application of Circuit Training in the regular physical education program in our schools (92).

- a. The student starts off easily and is able to experience some degree of success early in the program.
- b. The student is one of a class, but not asked to do anything beyond his own capabilities each day.
- c. The student, when ready, progresses to an individual circuit, based on his maximum performance.
- d. The student works inconspicuously among the other class members and is free from continuous direction from the instructor.
- e. Large numbers of students can work at the same time.
- f. The circuit selected should have a positive effect on muscular power, endurance and strength, and circulo-respiratory endurance.
- g. The exercises are easily standardized so that the student is able to perform the same way each day.
- h. The student knows exactly how he progresses each day. He can set a daily goal and objectively see how he is progressing toward it and toward the target time.
- i. Circuit Training is based on the work rate of the individual and employs the principle of "progressive loading" (a term used by Morgan and Adamson), which is the same as the "overload principle". Only in Circuit Training do you not increase the weight, but decrease the time it takes to perform the circuit, plus increasing the number of repetitions per exercise at specific times.

Evidence substantiating the value of Circuit Training in the public school situation appears somewhat limited and inconclusive. Brown (21) studied two groups of Grade Five girls. One group (experimental) participated in a ten minute per day, three times per week, eight week Circuit Training Program. The Circuit Training was performed during the first ten minutes of each physical education class. The remainder of the lesson consisted of the regular physical education class. A second group (control) participated in only the regular physical education program. The groups were tested before and after

the Circuit Training Program on the A.A.H.P.E.R. Youth Fitness Test.

Both groups made statistically significant gains in the total physical fitness scores. However, there was no statistically significant difference between these mean gains.

Adamson and Morgan (4:85) reported the following improvements shown by a class of school boys, fifteen years of age, who performed only ten minutes of Circuit Training per week for two months:

Exercise	Increase in Mean (as a percent of initial levels)
Trunk Curls	38
Rope Swing	28
Chins	55
Press Up	28
Steps (High Bench)	7
Squat Jumps	10

No mention was made of a control group or of statistical significance of the findings. A question arises as to whether the gains indicated are due to the treatment or due to development factors.

Circuit Training has proven to be effective at the university level.

Howell et al. (51) describe an experiment with Circuit Training in which two separate groups of fourteen university students were equated on the basis of scores on the Larson Strength Test. The experimental group did Circuit Training thirty-five minutes twice per week for three weeks. The con-

trol group took part in the regular physical education class activities. The experimental group made strength gains significant at the one percent level. The control group made no significant gains. The experimental group was significantly better than the control group at the one percent level of confidence.

In a study done by Monaghan (67), two groups of twenty males were selected randomly from university freshmen. The groups were tested on the Navy Standard (Modified) Physical Fitness Test. The experimental group did Circuit Training twice a week for twenty-five minutes, the control group participated in the regular physical education program. The experimental group showed statistically significant gains on all test items at the one per cent level of confidence. The control group showed gains in only two of the five items (sit-ups, pull-ups) at the one per cent level of confidence. The experimental group was statistically better than the control group on all but two of the five items (sit-ups, push-ups).

Watt (93), in a comparison of Circuit Training with another developmental course found that statistically significant gains in physical fitness levels can be achieved by low-fitness university students by taking part in either of the two programs. Exercise sessions were conducted two times a week for ten to twenty minutes a session.

Nunney (71), on studying the effects of Circuit Training on various swimming items during a six week training period, concluded that there was no significant evidence to show that

Circuit Training, which included exercises with weights, was in any way detrimental to swimming. Also the gains in swimming and speed made by the Circuit Training group suggest the combination is beneficial.

Adamson (2) studied the effects of Circuit Training on university men. He stated:

The following results were obtained in twenty students attending Circuit Training once a week for two months. They trained at half effort for half-an-hour.

		Increase in means (%)
Strength:	Grip	8.1
	Push and Pull	4.6
	Back	9.3
Muscular Endurance:	Chins	44.1
	Dips	76.4
Power:	Sargent Jump	12.3
General Endurance:	Step Test	6.9

In this study, however, no mention was made of statistical significance or of the use of a control group.

In three studies of university students, Circuit Training's value was not so clearly evident.

Howell, Hodgson and Sorenson(52) used two groups of seventeen subjects enrolled in required physical education at the university level. They were equated on the basis of a modified Harvard Step Test. The experimental group participated in Circuit Training twice a week for four weeks at twenty-five minutes per session. At the conclusion of the experimental period, all subjects were retested on the Modified Harvard Step Test. The experimental group showed a statistically

significant improvement, whereas the control group did not show a statistically significant improvement over the four week period. However, the final test between groups showed no significant differences.

Howell, et al. (51) studied two groups of ten university students who were equated on the basis of the Rogers' Strength Index (Oregon Simplification). One group (experimental) did Circuit Training twice per week for thirty-five minutes a session for six weeks. The control group participated in the regular class activities (badminton, volleyball, handball). The experimental group made strength gains significant at the one per cent level. The control group made gains significant at the five per cent level. Here again, however, the difference between the final means of the groups was not significant.

Hodgson (45) studied three equated groups of male university students. One group did Circuit Training three times per week ten minutes per session plus participation in two regular badminton classes less ten minutes per class. Another group did isometric exercises on the same schedule. A third group took part in the two full badminton classes per week only. The experiment lasted five weeks. All three groups made statistically significant improvements in treadmill performance times but the circuit group and the isometric group were not significantly different from the control group.

One study has shown the effectiveness of Circuit Training on adult males outside the university student population.

Taylor (84) has studied the effects of Circuit Training

on the cardiovascular and muscular status of business men. Circuit Training was shown to have a statistically significant effect on the results of the Larson Muscular Strength Test and the Harvard Step Test. Circuit Training was performed twice weekly for six weeks at forty-five minutes per session. A control group was used in the study.

Summary of Literature Reviewed on Circuit Training.

In summary, Circuit Training was shown to have an inconclusive effect on school children (4, 21), but to be effective in some applications at the university level (2, 51, 67, 71, 93). In other applications at the university level (45, 51, 52), the effects of Circuit Training were not clearly demonstrated. Circuit Training has been shown effective on business men (84).

Literature on the Astrand-Ryhming Test for the Prediction of Maximal Oxygen Intake.

Many exercise physiologists (12, 44, 69, 75, 88) consider the aerobic capacity (maximal oxygen consumption) of an individual to be the best measure of physical fitness or work capacity. This consideration is based on the assumption that all physical activity is eventually paid for by the utilization of foodstuffs and that oxygen is an essential ingredient in this process.

Hettinger, et al. (44), in agreeing that maximal oxygen intake is probably the best measure of physical fitness, pointed out that the method used to obtain the figure is time-consuming, requires fairly complicated laboratory procedures, and demands a high degree of cooperation from the subject. They stressed

the need for a simple work capacity test based on observations during submaximal work.

In 1954, Astrand and Ryhming (10) introduced a nomogram from which maximal oxygen intake could be predicted from a steady state pulse rate at a known work load. This device is referred to in several manners in the literature including the Astrand-Ryhming submaximal test, and more completely as the Astrand-Ryhming Test for the Prediction of Maximal Oxygen Intake.

The predictive value of the Astrand-Ryhming nomogram is based on the assumption that the heart rate and oxygen consumption of an individual are directly related during the performance of submaximal work (11, 18, 31, 37, 42, 44, 59, 61, 63, 85, 91). Astrand (11) warned, however, that heart rate gives only a rough conception of the individual's aerobic capacity. Wyndham (98) substantiated Astrand's warning by showing that a direct or rectilinear relationship between heart rate and oxygen consumption does not hold at higher work levels. He suggested that the nomogram has a tendency to underestimate maximal oxygen intake. Astrand (6) pointed out that error due to any tendency of the nomogram to underestimate was included in the given standard error of less than ± 10 per cent.

Validity and Reliability of the Astrand-Ryhming Nomogram.

Several studies have been done comparing maximum oxygen consumption values predicted from the use of the Astrand-Ryhming nomogram with those actually achieved in various recognized tests of maximal oxygen consumption (9, 10, 15, 35, 41, 44,

54, 80, 91). Results of these studies will be presented below in terms of per cent of difference for mean values in liters of oxygen consumed at a maximal rate per minute or as coefficients of the correlation of means achieved by the same subjects on both types of tests.

Astrand and Ryhming (10) validated the predictive capacity of the nomogram from results obtained from twenty-seven male and thirty-one female, well-trained subjects, 20 to 30 years of age. For two-thirds of the subjects (standard deviation) the means did not vary more than 6.7 per cent for males and 9.4 per cent for females. With lower rates of work (600 Kpm./min. for females and 900 Kpm./min. for males) the variations were slightly higher, 14.4 per cent for females, and 10.4 per cent for males. In addition, eighteen well-trained males 18 to 19 years of age were tested and the standard deviation for them was less than 7 per cent.

Astrand indicated in this same study (10) from a review of the findings of Wahlund (91) that because a fairly constant mechanical efficiency was achieved by Wahlund's subjects working on a bicycle ergometer, oxygen intake could be indirectly estimated from work loads within a range of ± 8 per cent in two-thirds of the cases.

Hettinger, et al. (44) used twenty eight male subjects 20 to 30 years of age and found the mean predicted maximal oxygen intake values about 9.7 per cent higher than the actual mean values (2.62 l./min. and 2.38 l./min. respectively). The difference was significant at the .05 level of confidence.

Hettinger felt the difference might be accounted for because his subjects appeared to be in much poorer physical condition than those used by Astrand and Ryhming in constructing the nomogram. However, a correlation between predicted and actual values was found to be significant at the .01 level of confidence.

In a group of nine Y.M.C.A. trained men, age 56 to 68 years, Astrand and Rodahl (9) predicted a maximal oxygen intake of three per cent above actual values (2.77 l./min. predicted and 2.241 l./min. actual). In twenty-two well-trained men, aged 23 to 48 years, a difference between mean predicted maximal oxygen uptake values (2.72 l./min.) and actual mean values (2.76 l./min.) was only 1 per cent.

Rowell, et al. (80), in predicting aerobic capacity from the Astrand-Ryhming Nomogram and comparing results with actual maximal oxygen consumption values, found under-predictions by the nomogram of actual values. In each of their cases the under -prediction was from 5.6 ± 4.2 per cent of actual maximal volumes of oxygen for endurance athletes through 26.8 ± 7.2 per cent for a sedentary group to 13.7 per cent in the same sedentary group after a conditioning program. These results show a marked trend toward improved prediction with increased physical conditioning.

DeVries and Klafs (35) studied a variety of predictive maximal oxygen intake tests on a bicycle ergometer. They compared predicted and actual values and found a correlation of 0.736 with the Astrand-Ryhming Nomogram when the units were

liters per minute. The Sjostrand Predictive Test in terms of Kpm./min./Kg. body weight gave a correlation of 0.877. The authors concluded, since the nomogram required only one work load, that no advantage was gained in using the Sjostrand Test.

Baycroft (15), using forty-eight male subjects between the ages of 17 and 35 years, in comparisons of the Astrand-Ryhming nomogram found correlations of 0.67 with the Mitchell, Sproule and Chapman (66) measured values and 0.62 with the Astrand Bicycle Test of actual maximal oxygen consumption (11). Values were computed in maximal number of liters consumed per minute. When values were considered in milliliters per minute per kilogram of body weight the correlations dropped to 0.53 and 0.47 respectively.

Glassford (41) compared the Astrand-Ryhming nomogram to three direct or actual maximal oxygen intake tests. He found correlations of 0.77, 0.62, and 0.63 when readings were made in ml./min./Kg. of body weight and respective correlations of 0.78, 0.72, and 0.65 when readings were made in liters per minute. He also found that the relationship between the nomogram values and any one set of values determined by a direct technique was as good as the relationship between the values of any two direct measures.

Hyde (54) studied twenty-nine male and twenty-seven female secondary school pupils to check the Astrand-Ryhming nomogram's validity compared to the Astrand (7, 9, 11) actual test of maximal oxygen intake. The performance of sexes was compared separately according to three conditions (54:49):

(I) the results from the actual (maximal) test were compared to the results of the predicted (submaximal) test when the predicted values were taken from the submaximal test which was held on a separate day from the actual test,

(II) the results from the actual test were compared to the results from the predicted test when the predicted values were taken from the first work level of the maximal test,

(III) the results from the actual test were compared to the results from the predicted test when the predicted values were taken from the second predicted test regardless of whether the predicted value came from the submaximal test or the first work level of the maximal test.

Results from each condition were given in liters per minute and in ml./min./kg. Correlations done on values expressed in liters per minute were significant for all conditions for both sexes except for females on condition (III). Correlations expressed in ml./min./kg. were significant for all conditions for males but for females only condition (II) proved significant. Only condition (I) proved significantly different from zero at the .01 level of confidence for both males and females. Correlations were 0.62 and 0.53 respectively. The tendency to achieve higher correlations when values are expressed in liters per minute compared to ml./min./kg. agrees with the findings of Glassford (41).

Hyde (54:65) also found that the nomogram has a tendency to underestimate the maximal oxygen consumption of secondary school males and females. The mean predicted values for males in liters per minute were significantly different at the .01 level of confidence from actual values on all three conditions listed above. For females, however, mean predicted values under conditions (I) and (II) are not significantly different.

Hyde pointed out, however, that the underestimation is

greatly decreased when one employs the correction factor for 15 year olds recently introduced by Astrand (14). He concluded that the test does differentiate between sexes and therefore can distinguish between high and low values of maximal oxygen consumption. This being the case, Hyde indicated that the nomogram may differentiate between well trained and less active individuals even though it may not be able to distinguish between the aerobic capacities of individuals who are in approximately the same state of training.

Larsson, et al. (62) compared the work capacity of six diabetic boys interested in sports with six non-diabetic boys of the same age and interests as the diabetics. The measured values for the maximal oxygen uptake were on the average 0.2 liters per minute higher than the values calculated from the Astrand-Ryhming nomogram. The calculated values were 7.9 per cent lower, but this difference was not significant. They concluded that the agreement between the measured oxygen capacity and that calculated from the heart rate demonstrated that the Astrand-Ryhming nomogram was applicable to adolescents, diabetics, and non-diabetics, as well as the 20 to 30 year old subjects for whom it was originally constructed. Nor, they concluded, was a correction factor necessary for the adolescent age groups as for individuals above 30 years of age.

Norman (70) evaluated twenty-three males and twenty-three females aged 14 to 18 years on two different days using the Astrand predictive test. Reliability coefficients in liters of oxygen consumed per minute were 0.84 for males and 0.71 for

females. When predicted maximal oxygen intake was expressed in kilograms of body weight, the coefficient remained at 0.84 for males but dropped to 0.53 for females. He concluded the coefficients were adequate to permit the detection of individual differences when expressed in liters of oxygen per minute.

Factors that Influence Maximal and Submaximal Oxygen Intake.

Certain factors appear to have an influence on the validity and reliability of tests used to predict or assess maximal oxygen intake. These include temperature of the test room, fatigue of the subject, food ingested by the subject, emotional state, and body dimensions of the subject, mechanical efficiency of the subject in performing test work, presence or lack of a warm-up session, sex and age of the subject and the physical condition or trained state of the subject.

Temperature. Williams, et al. (96) reported that a hot environment will increase the pulse rate for a given submaximal oxygen consumption but that maximum pulse rates are not altered. Rowell, et al. (cited in 88), using unacclimatized subjects, reported that in a hot environment maximal pulse rate was reached at a lower workload and that oxygen intake could increase as much as two liters per minute after this maximal pulse rate had been reached. Williams, et al. (96) attributed this largely to individual adaptation to heat, and suggested that if all experiments were conducted in an ambient temperature of about 65 degrees Fahrenheit these inter-individual effects would be minimized. Taylor, et al. (87) found that

room temperature was an important consideration in standardization of experimental conditions. They recommended a room temperature of 78 ± 4 degrees Fahrenheit as did Erickson, et al. (37), and Buskirk, et al. (22).

Fatigue. Lundgren (63) found that a day's work of eight hours in a lumber camp raised pulse rate and lowered oxygen consumption determined from submaximal work levels. He found that walking seven kilometers did not affect the pulse-rate per work-rate relationship but that walking 15 kilometers did.

Food Ingestion. Taylor, et al. (88) stated that even though we know that pulse rate and cardiac output are affected by food ingestion, not enough information is available to extrapolate to maximal levels. Lundgren (63) has found that breakfast increases pulse rate.

Emotion. Norman (70) felt that one of the major problems involved in the application of the Astrand-Ryhming nomogram in field studies was the apprehension that most subjects felt because of unfamiliarity with the test or what may be expected of them in its performance.

Taylor, et al. (88) state:

It is evident that the initial contact with a work test can result in significant increases in submaximal work pulse rate... It is clear that the submaximal pulse-rate work-rate relationship can be displaced to the left without an important rise in the maximal pulse rate.

Bengtsson (16) felt that apprehension's effects would be less marked during continuous and heavy work. Others (66, 83) thought that at submaximal work loads it was questionable whether

the mental factor had an effect.

Astrand (8) asserted that the heart rate and related functions of importance for the oxygen uptake and transport are definitely regulated within very narrow limits determined by the work output and fitness of the subject and are quite resistant to changes in the mental state of the subject.

Rowell, et al. (80) substantiated Taylor's statement above (88) from experiments using the Astrand-Ryhming nomogram in comparing tests with and without a tension producing factor (catheters inserted into the brachial arteries of subjects). In the tension producing situation there was a 6 per cent greater underestimation of maximal oxygen intake.

It would appear, then, that, although not conclusively substantiated, there is a possibility that pre-test apprehension may influence predictive test results.

Erickson, et al. (37) stated that oxygen consumption measured a second time on a treadmill gave a valid figure which did not change with additional experience. This may indicate that it is possible to overcome the effects of apprehension on predictive test results when the subject becomes more familiar with the test proceedings.

Mechanical Efficiency. If a test is going to be exactly reproducible, the mechanical efficiency of the subject on the test device must be kept constant. Wahlund (cited in 12) found a fairly constant mechanical efficiency on the bicycle ergometer, but Krogh and Lindhard (60) reported that subjects in areas where bicycle riding is not popular may show substan-

tial changes in mechanical efficiency with practice. Knehr, et al. (58) found that repeated bouts of work on the bicycle resulted in substantial a change in mechanical efficiency. Taylor (88) and Astrand (12) also agreed that mechanical efficiency could increase with practice or training. However, Rodahl, et al. (76) reported no statistically significant difference between the mechanical efficiency of nineteen Stockholm boys as compared to eighteen Philadelphia boys 14 years of age.

Norman (70) in a study of 415 secondary school girls and 500 secondary school boys found the female bicycle riders had higher aerobic capacities than female non-bicycle riders but for males this was not the case. The male non-bicycle riders were significantly higher in maximal volumes of oxygen in liters per minute and greater in body weight than the bicycle riders. However, when body weight was considered in expressing the predicted maximal oxygen intakes for boys, the mean value for non-bicycle riders fell below that of the bicycle riders although the difference was not now significant.

There appears, then, to be some question as to the utility of the bicycle ergometer in this regard. This problem may be alleviated somewhat should subjects have opportunity to familiarize themselves with the testing device. One might speculate that young people, more used to riding bicycles, may have greater mechanical efficiency on a bicycle ergometer than older people.

Age. Variations in maximal oxygen consumption between individuals are reduced with a reduction of the age of the

individuals (13, 77, 79). Increasing age is reported to cause a decrease in the aerobic capacity of an individual after age twenty to thirty (6, 77). Wyndham and Ward (97) postulated that this reduction in aerobic capacity might have been a result of decreased pulmonary-arterial diffusion.

Sex. Several studies (11, 16, 65) show that the physical work capacity or maximal oxygen consumption of females beyond the age of puberty (about 14 years) is markedly lower than that for males. The aerobic capacity of females is also lower than males for younger age groups, but the difference is not as pronounced (1, 11, 16).

Body Dimension. Body weight has been shown to be related to maximal oxygen consumption by Robinson, et al. (77, 79), Wyndham, et al. (98), Buskirk (23), Buskirk and Taylor (22), Coyne (29), Welch, et al. (94), and others (11, 35, 88).

Taylor (86) showed that in submaximal exercise the correlation between oxygen consumption and weight was 0.71 and for maximal work efforts 0.43. This indicates that in submaximal work, oxygen consumption was chiefly a function of body weight and only slightly related to fitness ($r=-0.20$) but in maximal work the relation with weight dropped markedly and the correlation with the fitness criterion rose considerably.

Norman (70), in his study of 417 secondary school girls and 500 secondary school boys, concluded that the commonly used procedure of equating subjects by dividing maximal oxygen

values by their body weight overcompensated for the influence body weight has on these values for this age group (15 to 19 years).

He also concluded that because of the close relationship between height and weight in this age group it was not meaningful to express maximal oxygen intake per unit of height or per unit of body surface if surface area was calculated as a function of height and weight.

Training. Norman (70) stated that the Astrand predictive test distinguished between "highly active", "moderately active" and "not active" individuals when values were expressed in relation to the body weights of the secondary school boys and girls tested. Knehr, et al. (58) found a 7 per cent increase in maximal oxygen intake for fourteen men studied over a period of six months of training. Robinson (78) found training increased maximal oxygen consumption by 16 per cent. Karpovich (57) reported that an untrained man may have a maximal oxygen consumption of two liters per minute and a trained athlete may double this amount. Buskirk and Taylor (22) and Dempsey (34) found higher maximal oxygen intakes in individuals undergoing regular physical exercise.

Summary of Literature Reviewed on the Astrand-Ryhming Nomogram.

To summarize, many exercise physiologists consider the maximal oxygen consumption of an individual the best measure of physical fitness or work capacity (12, 44, 69, 75, 88). Direct maximal oxygen consumption is difficult to measure (44).

Astrand and Ryhming (10) have constructed a nomogram for the prediction of maximal oxygen consumption. The test is relatively simple to administer. The predictive value of the nomogram is based on the assumption that heart rate and oxygen consumption are directly related during the performance of submaximal work (11, 18, 31, 37, 42, 44, 59, 61, 63, 85, 91).

Several authors have found the nomogram overestimates maximal oxygen consumption (9, 44), others have found it underestimates maximal oxygen consumption (54, 62, 80, 98). Three studies have found positive correlations, significantly different from zero, between the nomogram and various actual tests of maximal oxygen consumption (15, 41, 54). One study found that the relationship between the nomogram values and any one set of values determined by a direct technique was as good as the relationships between the values of any two direct measures (41). The predictive method was found to be more reliable when values were expressed in liters per minute (males - $r = 0.84$, females - $r = 0.71$) than in milliliters per kilogram of body weight ($r = 0.84$ and 0.53) (70).

Certain factors appear to have an influence on the validity and reliability of tests used to predict or assess maximal oxygen intake. The temperature must be constant and within the range of 65 to 82 degrees Fahrenheit (22, 37, 87, 96). Fatigue can lower predicted values (63), as can ingestion of food (63, 88). Emotional apprehension may lower predicted maximal oxygen consumption values (70, 80, 88), although some authors disagree (8, 66, 83). Familiarity with

the test procedure may reduce apprehension (37, 70). Certain authorities imply that mechanical efficiency on a bicycle ergometer is constant enough not to influence results (12, 76). Others feel the results may be influenced, particularly if subjects are unfamiliar with bicycle riding (58, 88).

In young people, more familiar with bicycle riding, the results do not appear to be as greatly influenced by the result of learning on the bicycle ergometer (70, 76).

Sex (11, 16, 65) and age (13, 77, 79) must be considered in equating groups when comparing results from the predicted test.

Body weight has been shown to be related to maximal oxygen consumption (11, 22, 23, 29, 35, 77, 79, 88, 94, 98). One study concluded that the commonly used procedure of equating subjects by dividing maximal oxygen values by their body weight over-compensated for the influence body weight has on values for fifteen to nineteen year olds (70).

Training increased maximal oxygen consumption (22, 34, 57, 58, 78). In particular, one study found that the Astrand predictive test distinguished between "highly active", "moderately active" and "not active" individuals when values were expressed in relation to the body weights of the secondary school boys and girls tested (70).

Literature Related to the Testing of Strength.

In this study, strength was defined as the capacity of a subject to apply a recordable force to an instrument, through the use of an isometric contraction developed by one or more

muscle groups of the body (53:4). The instruments used were the same as those used by Howell, et al. (53) in their study of Edmonton school children.

Howell - Loiselle - Lucas Strength Testing Method

Reliability Checks. In the study carried out by Howell, et al. (53), individuals were given three trials on each of the tests used. It was decided to check the reliability of the tests from the results of the first and second trials for each test. The results of the reliability checks, presenting ages, numbers of subjects and sexes, are given in Tables I and II (53: 71, 72). Reliability is noted to be high on these checks, ranging from 0.64 to 0.97.

TABLE I

TEST RETEST RELIABILITY COEFFICIENTS FOR FEMALES

Age	7	8	9	10	11	12	13	14	15
No. of Subjects	36	43	45	46	43	41	32	32	30
Grip-Right	0.80	0.82	0.84	0.78	0.81	0.87	0.94	0.79	0.90
Grip-Left	0.80	0.96	0.87	0.84	0.77	0.91	0.85	0.83	0.85
Elbow Flexion	0.90	0.70	0.91	0.90	0.92	0.94	0.93	0.94	0.90
Elbow Extension	0.83	0.81	0.93	0.92	0.95	0.97	0.92	0.89	0.88
Knee Extension	0.89	0.89	0.87	0.86	0.93	0.86	0.86	0.82	0.93
Leg Lift	0.92	0.88	0.91	0.88	0.92	0.95	0.91	0.93	0.93
Back Lift	0.88	0.93	0.93	0.83	0.90	0.94	0.87	0.85	0.79

TABLE II
TEST RETEST RELIABILITY COEFFICIENTS FOR MALES

Age	7	8	9	10	11	12	13	14	15
No. of Subjects	43	40	33	40	48	36	37	31	33
Grip-Right	0.73	0.81	0.83	0.95	0.90	0.89	0.97	0.81	0.94
Grip-Left	0.86	0.87	0.92	0.90	0.95	0.94	0.90	0.78	0.89
Elbow Flexion	0.86	0.88	0.91	0.94	0.87	0.91	0.93	0.87	0.94
Elbow Extension	0.88	0.90	0.93	0.91	0.95	0.98	0.89	0.95	0.97
Knee Extension	0.85	0.82	0.74	0.86	0.88	0.88	0.94	0.98	0.98
Leg Lift	0.87	0.88	0.89	0.64	0.87	0.93	0.92	0.91	0.93
Back Lift	0.59	0.91	0.84	0.88	0.79	0.91	0.94	0.81	0.94

The second type of reliability coefficient appears in Table III (53:72). These reliabilities were computed from subjects who were given a complete retest. The mean test-retest interval was 20.15 days and the range was 7 to 22 days. The mean age of the group was 176.9 months. Picked at random, they included some subjects fourteen years and some fifteen years of age. Females and males were included. The coefficients ranged from 0.81 to 0.96. It was concluded that the test procedures were highly reliable (53:156).

TABLE III
TEST-RETEST RELIABILITY COEFFICIENTS

Grip- Right	Grip- Left	Elbow Flexion	Elbow Extension	Knee Extension	Leg Lift	Back Lift
0.91	0.95	0.96	0.84	0.90	0.81	0.92
N = 23	N = 23	N = 21	N = 21	N = 21	N = 21	N = 20

Literature Related to Strength Characteristics of School Aged Boys and Girls.

Espenschade (38), in 1947, using longitudinal and cross-sectional data, found only slight sex differences existed in strength before the age of 13.8 years, with boys excelling after this time.

Jones (56) compared strength measures of girls in the pre-menarcheal state of development to girls of the same age in the post-menarcheal state and found the latter to be stronger. He concluded that strength was more closely related to physiological age than to chronological age.

Jones (55) reported on the California Adolescent Growth Study in 1949. He found that until age thirteen males were about 8.8 pounds stronger than girls. The largest gain in right grip among males occurred between 14.5 and 15.0 years, and among females between 12.0 and 12.5 years.

From strength results obtained from a large sample group of nine to seventeen year old boys, Bookwalter (19) found a

slight strength progression from nine to fourteen years. Progress was accelerated from fourteen to seventeen years. He found right grip strength to be consistently greater than left grip strength although handedness was not known.

In a large sample in Ceylon, Cullumbine, et al. (30) found female grip strength to be inferior to male grip strength.

Phillips (73) found the grip strength of boys to be significantly greater than that of girls of the same age.

Using a sample of five thousand, Hall (43) found boys and girls at age ten to have similar strength scores. At age nineteen the average for boys on arm pull was 326 pounds, while girls averaged only 194 pounds. The largest increase occurred earlier for girls (11.25 to 13.9 years) than for boys (13.75 to 16.25 years).

Buxton (24) confirmed Hall's (43) results on measures of leg strength. Boys and girls were similar at age ten with rapid gains for girls around eleven years and boys making rapid gains between thirteen and fifteen years.

With a male sample aged nine to fourteen, Clarke and Carter (27) found a right and left grip strength correlation of 0.72 to 0.87 in range.

Torpey (89) found right knee extension scores by the cable tension method to be higher for males than females from grades one through to six.

Fleishman (40), working with large sample groups, found that girls aged fifteen had hand grip strength 12 pounds greater on the average than fourteen year olds. For boys large

mean differences occurred between ages thirteen, fourteen and sixteen years.

One of the findings of Howell, et al. (53:156, 157), was that boys and girls differed significantly on all of the ten measurements employed (including grip, arm, back and leg strength tests) except for leg extension and leg lift at ages eight, and nine. Boys and girls differed significantly on all measures taken without exception at ages fourteen and fifteen, boys being stronger. At ages eleven and twelve years, and to a lesser extent at ages ten and thirteen, there were little or no sex differences occurring for strength measures used in the study.

Summary of the Literature Reviewed on Strength.

To sum up, strength was defined according to the amount of force recorded on an instrument (53). The reliability of strength measures used in this study was checked by Howell, Loiselle and Lucas and found to be highly reliable (53:152).

Many studies have shown that school aged boys are generally as strong as or stronger than school aged girls (24, 30, 38, 43, 55, 73, 89). From the onset of puberty onward, boys appear to gain strength more readily and to a greater extent than do girls (24, 30, 38, 43, 53, 55). Girls were usually found to reach puberty and to make rapid strength gains at an earlier age than boys (between eleven and thirteen years for girls and thirteen to fifteen years for boys) (24, 30, 43, 53, 55). Girls were found to be stronger after puberty than before (55).

CHAPTER III

METHODS AND PROCEDURE

The Circuits.

Three types of Circuit Training were employed in the study. The students in the experimental groups performed the circuits in rotation with a different circuit done each day for three days when the cycle would then be repeated. This routine was followed throughout the experimental period. A variety of circuits was employed in an effort to reduce boredom and keep interest high. Each circuit consisted of six stations and an additional supplementary station making seven stations per circuit in all.

The regular circuit consisted of the following isotonic exercises: chins, knee bends, push-ups, bench jumps and skips. The supplementary station was the "Matterhorn", a peg board used for climbing. A description of each circuit and its administration is given in Appendix D.

The weight circuit was performed around a moveable weight storage cart in the gymnasium center. Exercises included two arm curls, bench presses, squats or knee bends, bench jumps, two arm presses and dumbbell swings. The "Matterhorn" was supplemental. All exercises required the use of weights.

The endurance circuit involved the running of laps around the perimeter of the gymnasium floor. A station on this circuit was defined as two laps. A circuit consisted of six stations or twelve laps. Completion of two circuits was roughly equivalent to running one mile. The supplemental

station on the endurance circuit was also the climbing of the peg board "Matterhorn".

Class Routines and the Set Piece Method.

Class routines for experimental classes (groups) and control classes (groups) were similar except that control classes had ten minutes of Structured Play to apply skills being learned, whereas experimental classes had Circuit Training. Classes were forty minutes in length.

The experimental classes were organized in what shall be referred to as the "set piece method" of organization. A set time of twenty minutes was allotted for the recurring routine activities of changing costume, Circuit Training, and the taking of notes.

In order to compensate for the variable of time used by each student to accomplish these tasks, the third circuit was used as a "buffer" activity. That is, after note taking, faster students had time for all or part of a third circuit, while slower students would be able to do two circuits only before copying notes. If slower students were not able to finish copying notes, the final required routine activity, before the twenty minute set piece of the class concluded, a record was made of the fact by the teacher. Such students were required to present the completed work at a later date or suffer a reduction in their mark.

The remaining class time (twenty minutes) was devoted to discussion of the notes (five minutes), and to the assimilation and practice of skills (fifteen minutes). When the skill

level achieved was satisfactory in a specific activity, Structured Play in the activity was substituted for practice.

The control classes used a modified "set piece" method of organization. The set piece was shortened to ten minutes and included only changing and note taking. The "buffer" activity for those who finished the routine activities under ten minutes was shooting free throws in basketball. This activity was selected even though it did not always correlate with the activity under study because it was universally popular, it required little direct supervision, it was relatively safe, it occupied a definite and limited space, achievement was easily measured and no day to day instructions were needed to ensure the continuity of the system.

Following the set piece of each control class, various skills were taught and practiced. Fifteen minutes were used for this function. Finally, the last ten minutes of each class were used for Structured Play purposes. When skill level became sufficiently high, Structured Play situations were employed for the final thirty minutes of the class period for several days to culminate the specific unit of study.

Both experimental and control classes had the same set of notes given them in each grade and were taught the same skills on the same days. The only planned-for difference was that the experimental group did Circuit Training while the control group did Structured Play.

Motivation on the Circuit.

Day to day motivation of students to work hard on the

Circuit Training Program was a prime consideration. No marks were given for circuit achievement because experience over several years showed that this tended to cause Short Circuiting by students. The following devices were employed to motivate students in performing the circuits.

1. The students were instructed about the necessity of activity in maintaining healthy growth and development.
2. The idea of competing against one's self was stressed.
3. Daily records were kept showing any reduction in time needed to complete two circuits by each student.
4. Daily records of the number of circuits completed by each student were kept.
5. Distinctive colored ribbons to be worn on the gymnasium costume were awarded to students who were monitored on the circuits and judged to have performed them with great enthusiasm, honesty and vigor (see Appendix D).
6. Students were monitored at random while performing circuits. They were informed of any Short Circuiting observed. A note was made of any such deviations observed.

In addition, it was necessary to inform students that an experiment was in progress and they were aware that achievement was being measured by the indices employed in the study. This fact, unfortunately, set up an artificial motivating factor which would not be present in a normal operational setting.

Design of the Study.

Because junior high school girls and boys were used as subjects, the study was divided into two parts, one for girls

and one for boys. A total of sixty boys, twenty-nine in Grade Eight and thirty-one in Grade Nine were employed in the boys' study. A total of thirty-eight girls, twenty-one in Grade Eight and seventeen in Grade Nine were used in the girls' study. One male subject left the school after the final oxygen test, but before the final strength test. He was not included as a subject in the strength evaluation. Methods and procedures for each part were identical.

All of the subjects tested were able to take part in the regular physical education program of the school which consisted of a daily, forty minute period, five days per week, over the ten week experimental period. Two Grade Nine and two Grade Eight classes of mixed sex were used. The subjects were enrolled at Devon High School, Devon, Alberta.

Subjects were tested on the Astrand-Ryhming Predictive Test of Maximal Oxygen Consumption (10). Their strength was determined by the Howell-Loiselle-Lucas (53) strength measurement techniques. Tests were made in the week prior to the beginning of the Circuit Training Program and in the week after the program finished.

An array of the scores for each sex on the summed strength measures was calculated. Each array was blocked into quarters or quartiles according to the method suggested in A.A.H.P.E.R. Research Methods (82:297).

The maximal oxygen consumption scores expressed in liters of oxygen per minute were arrayed within the quartile blocks achieved from the strength scores. These scores were

then evenly allotted to one of two groups for each sex in each grade. The method used was to pair oxygen scores beginning with the two lowest scores in each strength quarter block and progress upward to the two highest scores. Individuals within each pair were assigned to one or other of the two groups by a toss of a coin.

The result was two imperfectly equated groups on two variables (oxygen consumption and strength) for each sex. The groups within each sex were tested by a two-tailed test of t (39) on each variable to ensure that they were not significantly different from each other prior to the Circuit Training Program. There was found to be no difference between groups within sexes on either variable at the 0.05 level of confidence.

Because it was necessary to have two mixed classes for each grade, imperfectly equated groups of the same sex in a grade were paired with groups of the opposite sex in the same grade to make up the classes. A total of four mixed classes resulted, two in Grade Eight and two in Grade Nine. Classes within grades were assigned randomly to either the experimental treatment or the control treatment. The end result was a co-educational experimental class in Grade Eight and in Grade Nine and a co-educational control class in Grade Eight and in Grade Nine. Although the classes were co-educational, only subjects of the same sex in control and experimental classes were compared statistically on the oxygen and strength variables.

As initial testing took place the first week of October, it was necessary to arrange before the start of the school year

to timetable the physical education classes for each grade in consecutive periods alternating with another subject that all students were studying. Permission from the Devon County School Committee, the Principal and the Teacher involved was granted. The alternate subject was science. This allowed class composition to be changed within grades to facilitate structuring the experimental and control classes. The Circuit Training Program was conducted over a 10 week period with the final testing session occurring in the week immediately following the training program.

The Astrand-Ryhming Test for the Prediction of Maximal Oxygen Intake.

The apparatus for prediction of maximal oxygen intake was brought to the school before the opening of the term on September 1, 1966. The apparatus consisted of a Monark GCl Bicycle Ergometer, a Sanborn Twin-Viso Recorder Model 60-1300 electrocardiogram, an electric metronome and a stop watch with precision of 1/10 of a second. All subjects were exposed to the apparatus and the purpose of the study was explained to them. In the class periods prior to the initial testing period all subjects had a chance to take an unofficial test to allow them to become familiar with the test procedure and the apparatus.

During the week of initial official testing, a second physical education teacher and selected high school students assisted in the procedure. A record was kept of the order, day and time that each subject took his/her test and the same

routine was repeated for the final test at the end of the training program in December.

The testing procedure closely followed the description given by Astrand (14) and Hyde (54). The bicycle ergometer was carefully adjusted before each test so that the pendulum weight was set at "0" in order that the work load could be precisely set.

The subject, dressed in gymnasium costume, then mounted the bicycle ergometer and the seat was adjusted to the individual's comfort. Normally the subject sat so that the front part of the sole of his/her foot was placed on the pedal and the front part of the knee was straight above the tip of the foot. The metronome was set at 100 single beats per minute and the subject was allowed to pedal against a zero work setting until he/she could pedal at the correct cadence. The work load was then set and the stop watch started. This load was set subjectively but normally the boys started at a work load of 600 Kpm./min. while the girls began at 300 Kpm./min. Heart rates were taken from the electrocardiogram at the conclusion of each minute of exercise and converted to beats per minute.

After 4 - 5 minutes the pulse rate usually reached a steady state and the mean pulse rate between the fifth and sixth minute was designated as the working pulse. If a steady state was not found at this time, the exercise continued until a constant level was reached. If the pulse rate reached the steady state between 125 and 170 beats per minute after

6 minutes the test was terminated. If the initial work load was not heavy enough to raise the pulse rate of the individual over 125 beats per minute the work load was increased until a steady state within the required range was attained. An attempt was made to have the individual reach the steady state at approximately 150 beats per minute since the predicted value is considered more accurate at higher pulse rates (6).

The individual's maximal oxygen intake was then determined from the steady state heart rate and work load by employing the nomogram prepared by Astrand and Ryhming (10) (Appendix B).

The Howell - Loiselle - Lucas Strength Measuring Techniques.

It was not possible to bring the strength testing apparatus to the school before the initial official testing began and students were not able to familiarize themselves with the equipment and its operation before the initial testing period. The devices used were the same as those employed by Howell, Loiselle and Lucas (53) and every effort was made to duplicate their administration of the tests. Testing was carried on at the same time and by members of the same group of people as for the predicted oxygen consumption test. All subjects were encouraged to do as well as possible on each test. The following is a description of the apparatus and techniques used, paralleling the methods taken from Howell, et al. (53:51).

Strength Testing Machine. The strength testing machine, which followed a Hettinger idea, was used for eight of the

ten tests of basic strength carried out. A vertical pole six feet long was attached to a heavy metal base that was three feet square. To the pole was attached a seat which could be lifted or lowered to accommodate subjects of unequal sizes. Two seats were interchangeable, one a small toy tractor seat for the younger or smaller subjects, and the other a regular tractor seat for all the other subjects. Slightly higher on the pole was a shaft to which horizontal arms were attached. To the horizontal arms two elbow holders were fastened. The elbow holders stabilized the upper arms both vertically and laterally. They were completely adjustable through use of a sliding, but lockable system. The third attachment to the vertical pole held two shoulder pads, which were adjustable. These adjustable pads stabilized the shoulders to prevent both excessive lifting of the shoulders and forward rotation. A V bar was attached to the top of the vertical pole. The V bar was used to attach a chain during the elbow extension tests. The base of the apparatus contained a set of adjustable hooks to which chains could be fastened for the elbow flexion and leg extension tests. The machine was completed by addition of short chains, precision width cables, web-belt loops and hooks, and a Pacific Scientific Instrument cable tensiometer. The grip strength test was carried out with the subject seated on a chair, using a Smedley Adjustable grip dynamometer.

Back and Leg Lift Apparatus. The back and leg lift measurements were both carried out using a small stool upon

which the subjects stood. A cable was attached to a bolt just beneath the surface of the stool. A metal gripping bar and a web belt were used for the leg lift. The belt was not used for the back lift. A Pacific Instrument Company cable tensiometer was used to record the strength of each pull. Leg angle was checked by a gonimometer, and was set at 120 degrees flexion.

Description of the Strength Tests.

Grip Strength Test. The strength of grip was tested for each hand by means of a Smedley Adjustable Grip dynamometer. After being seated the subject was instructed as to the manner of carrying out the squeeze action. The testing arm was flexed as far as possible, and the hand held the dynamometer with the dial facing away from the subject. For female subjects the adjustable dynamometer was set to number four position, while for males the setting was number five. The hand was neither supinated nor pronated but was vertically positioned while doing the test. Turning or rotating of the hand was not allowed. As the subject commenced the grip action he dropped his lower arm until it reached 90 degrees flexion. The subject was allowed six seconds for each squeeze. A brief rest was allowed between trials while the reading from the dynamometer was taken and recorded. After two maximum effort trials with the left hand, the subject carried out two with the right hand. Verbal encouragement or the shout technique was used at all times during the test. The subject was not aware of the results during the testing period.

Elbow Flexion Test. This test was carried out by the use of the strength machine after the shoulder and elbow holders had been adjusted. These adjustments consisted of having the subject assume a comfortable upright sitting position with the shoulders back and evenly balanced; and of having the subject's elbows against his sides and adjusted forward or backward so his upper arm was vertical. The hands remained vertical and clenched throughout the test. Using a goniometer the angle at the elbow was adjusted to 120 degrees. A belt loop was then placed around the arm and positioned exactly midway between the wristbone and the olecranon process. A cable and chain was snapped to the loop and attached to the adjustable hook at the base of the machine. The hook was adjusted to the perpendicular with the lower arm, such that the angle of pull was straight. Using a Pacific cable tensiometer attached to the cable the subject flexed against the taut cable as hard as possible for six seconds. As with the grip test each subject did two tests with his left arm followed by two tests with his right arm. Verbal encouragement and brief rests were used throughout.

Elbow Extension Test. The overall technique was exactly as for the elbow flexion test. The differences in technique included: adjusting the angle of the elbow to 90 degrees; attaching the cable and chain to the V arm of the strength machine, which is located at the top of the vertical pole; and having the subject extend his lower arm downwards against the taut cable emphasizing bending of the lower arm at the elbow

rather than pushing. The tendency to push was opposed by the opposite shoulder pad.

Knee Extension Test. The subject remained in the strength machine with his hands placed lightly on his legs. A belt loop was placed around the subject's lower leg midway between the malleolus and the patella. The angle at the knee was adjusted to 120 degrees. The cable and chain was then fastened to one of a series of hooks placed at the perpendicular to the lower leg and adjusted laterally so that the angle of the pull was zero. The experimenter held an object in line with the proper angle of pull such that the subject's maximal extension was properly aligned. Two extensions with the right leg were followed by two with the left leg. Brief rests were used along with the shout technique in doing the test. The subject left the strength machine after the knee extension test.

Leg Lift Test. The test of leg lift strength was similar to that described by Clarke (26). A small twelve inch stool was placed against a flat wall. The subject stood on the stool with his feet parallel and shoulder width apart. A metal bar was gripped by the subject with one hand prone and one supine, and with arms bent. Attached to the bar and leading around the subject's back at hip level was a three inch web belt, which aided the subject in performing a maximal lift. The belt rested just over the top edge of the iliac crest. After adjusting the knee angle to 120 degrees and checking to see that the subject's back was against the wall the subject

pulled vertically upward by attempting to straighten his legs. A taut chain and cable prevented this, and held the Pacific Instrument cable tensiometer. The subject performed two maximal leg lifts.

Back Lift Test. The back lift was similar to the Clarke (26) back lift. The belt used for the leg lift was discarded but the subject remained on the stool. The subject bent forward at the hips and with arms straight he grasped the bar. The legs were straight throughout the test. The chain and cable were adjusted so that with a maximal back lift the subject's back ended up just vertical or touching the wall. Hand position and the number of trials remained the same as previously.

The highest reading on each test was summed and the resulting total became the subject's summed strength score.

Equipment Calibration.

All calibration of the tensiometers was carried out by the instrument Laboratory of Northwest Industries Limited of Edmonton.

The sinus balance on the bicycle ergometer was calibrated by means of a set of stainless steel weights, #750 Class S - 1 Serial No. 7Y1458 in the following manner (14):

- a) The brake drum was removed and the mark on the pendulum weight was set at "0".
- b) A one kilogram weight was attached to the spring. Weights were added or taken from the spring as required to bring

the mark on the pendulum to the required scale mark of "1-Kp".

c) The process was continued through "2 Kp", "3 Kp" and so on up to "7 Kp".

d) If adjustment was required it was made by means of an adjusting screw which altered the center of gravity of the sinus balance.

Statistical Treatment.

Two tailed tests of t (39) were used to test the significances of the differences between means of the indices exhibited by the various experimental and control groups prior to the Circuit Training Program.

An analysis of variance as outlined by Edwards (36:227) was used to test the hypotheses presented in the statement of the problem.

CHAPTER IV

RESULTS AND DISCUSSION

In considering the data in the analysis of variance tables to follow, the A effect or Groups effect essentially compares the scores of the experimental or Circuit Training group taken both before and after the Circuit Training Program and considered as a mean with the scores of the control or Structured Play group also taken before and after the program and considered as a mean. If the A effect be significant, the combined scores of the experimental group represent a different population than the combined scores of the control group. As the scores of both groups taken before the program were assumed to represent the same population, changes in the scores taken after the program must be marked enough to compensate for this previous similarity in order to result in a significant A effect.

The B effect or Trials effect essentially compares the overall mean of the two groups before the Circuit Training Program with the overall mean of the two groups after the program. Significance indicates that one or both groups have changed significantly from their initial status.

The AB, Groups by Trials or interaction effect is probably the most relevant in this study. It compares differences between the experimental group considered before and after the Circuit Training Program with differences between the control group considered before and after the program. Significance

indicates that changes in the experimental group are significantly different from changes in the control group.

Results of Effects on Boys of Circuit Training in Terms of Oxygen Consumption.

The Circuit Training or experimental group consisted of thirty-one boys and the Structured Play or control group of twenty-nine boys. Table IV represents the analysis of variance in predicted maximal oxygen consumption in liters per minute for group, for trials, and for the interaction of groups and trials.

Figure 1 shows the comparison of mean predicted maximal oxygen consumption values in liters per minute between groups for both the before and after experiment trials.

A t-test of significance (39) was used to compare the mean of the control group to that of the experimental group before the Circuit Training Program. The calculated t-ratio was .505, a value that was not significant at the 0.05 level of confidence.

Figure 1 indicates that the control group decreased slightly in mean predicted maximal oxygen consumption in liters per minute, the initial and final means being 2.35 and 2.33 liters respectively. The experimental group increased from a mean value of 2.42 liters to 2.60 liters.

Table IV shows that the experimental groups' increase and the control groups' decrease were not great enough to bring about a significant F-ratio for Groups ($P = 0.05$). The F-ratio for the A effect was 1.508 and a value of 4.010

TABLE IV

ANALYSIS OF VARIANCE - BOYS - PREDICTED MAXIMAL OXYGEN VALUES

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F	Significant P=0.05
A Groups	.8823	1	.8823	1.508	
error a	33.9199	58	.5848		
B Trials	.1895	1	.1895	4.761	✓
AB Groups x Trials	.3035	1	.3035	7.625	✓
error b	2.3110	58	.0398		
TOTALS	37.6062	119			

$\bullet_1$ - Experimental Groups Before $\bullet_2$ - Experimental Groups After
 $\circ_1$ - Control $\circ_2$ - Control

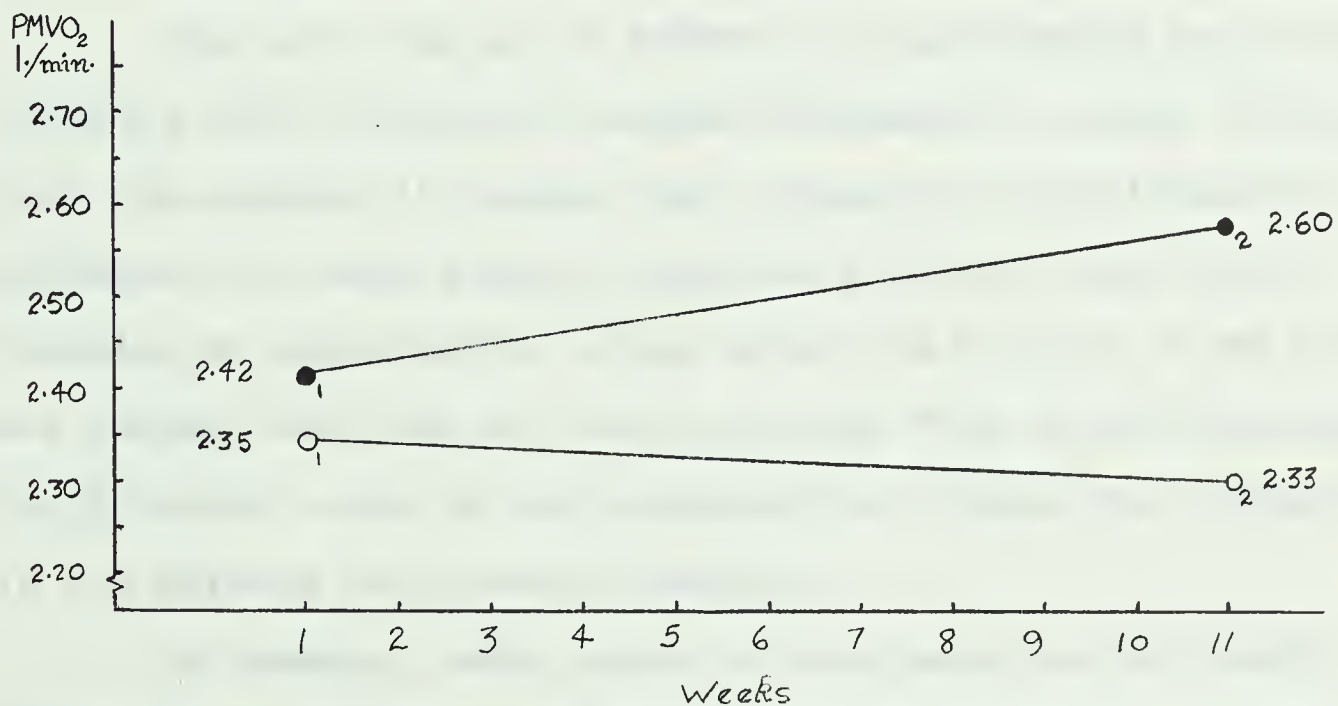


FIGURE 1

Comparisons of mean predicted maximal oxygen consumption values (PMVO₂) in liters per minute for Boys' Groups both Before and After the Circuit Training Program.

was needed for significance at the 0.05 level of confidence. In the following discussions, achieved and required F-ratios are shown as a fraction in brackets with the numerator representing the achieved F-ratio and the denominator representing the F-ratio required for significance with $P = 0.05$. For example, the above would be represented as (1.508/4.010).

A significant Trials effect was achieved however (4.761/4.010). One may therefore reason that the after experiment oxygen scores of one or both groups differ significantly from respective before experiment scores. However, it cannot be said with confidence that the groups, having changed, have changed differently.

The fact that an AB effect of significance was achieved (7.625/4.010) for boys in oxygen consumption values indicates that the changes in groups over trials were significantly different for each group. The mean score of the Circuit Training or experimental group after the program (2.60 liters) was larger than that of the Structured Play or control group (2.33 liters), and we may reasonably attribute the difference to the effects of Circuit Training.

In summary, both groups of boys were statistically equal in mean predicted maximal oxygen consumption values before the experiment. No significant Groups effect was achieved. A significant Trials and Groups by Trials effect resulted. The mean of the experimental group increased, while that of the control group decreased. The difference may be attributed to the effect of Circuit Training.

Results of the Effects on Girls of Circuit Training in Terms of Oxygen Consumption.

Table V represents the analysis of variance in predicted maximal oxygen consumption in liters per minute for girls' experimental (n = 18) and control (n = 20) groups.

Figure 2 shows the comparison of mean predicted maximal oxygen consumption values in liters per minute between girls' groups before as well as after the experiment.

A t-test of means (39) indicated that the control and experimental groups were initially matched. The calculated t-ratio was 1.013, a value not significant at the 0.05 level of confidence.

Figure 2 shows that the control group decreased slightly in mean predicted maximal oxygen consumption in liters per minute, changing from 1.84 liters to 1.81 liters. The experimental group increased from a mean value of 1.95 liters to 2.15 liters.

Table V indicates there was no significant Groups effect for girls in oxygen consumption (3.663/4.110).

No B or Trials effect was achieved by the girls in oxygen consumption, meaning that the groups did not change significantly from initial values (3.138/4.110).

It is important to note, however, that the changes made in groups, when compared to each other, did indicate significance. This is demonstrated through the achievement of a significant F-ratio on the AB effect (7.141/4.110). Changes made by groups were significantly different from

TABLE V

ANALYSIS OF VARIANCE - GIRLS - PREDICTED MAXIMAL OXYGEN VALUES

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F	Significant P=0.05
A Groups	.9887	1	.9887	3.663	
error a	9.7146	36	.2699		
B Trials	.1114	1	.1114	3.138	
AB Groups x Trials	.2535	1	.2535	7.141	✓
error b	1.2769	36	.0355		
TOTALS	12.3451	75			

Experimental Group - Before - $\bullet_1$ - After - $\bullet_2$
 Control Group - Before - $\circ_1$ - After - $\circ_2$

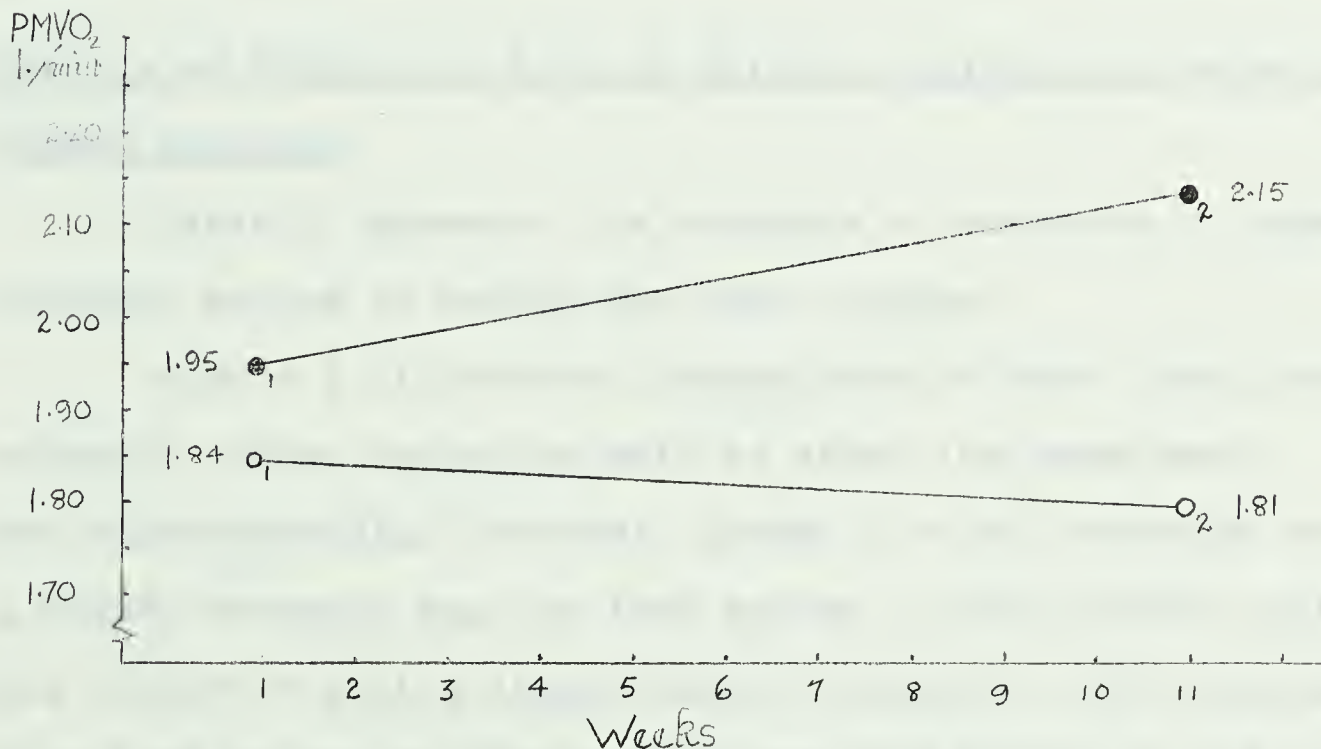


FIGURE 2

Comparisons of mean predicted maximal oxygen consumption values (PMVO₂) in liters per minute for Girls' Groups both Before and After the Circuit Training Program.

each other. As the Circuit Training or experimental group increased its oxygen consumption capacity, while the Structured Play or control group decreased slightly, one may reason that the difference was due to the effects of Circuit Training.

To summarize, both groups of girls were statistically equal in oxygen consumption values before the experiment. No significant Groups or Trials effects resulted from the experiment. A significant Groups by Trials effect was achieved ($P = 0.05$). As the experimental group increased its oxygen consumption capacity while the control group decreased, the difference may be attributed to the effects of Circuit Training.

Results of Effects on Boys of Circuit Training in Terms of Summed Strength.

Table VI presents the analysis of variance in summed strength scores in pounds for boys' groups.

Figure 3 illustrates comparisons of boys' mean group strength values before as well as after the experiment. The Structured Play (control) group ($n = 29$) increased from a summed strength mean of 1385 pounds to 1513 pounds while the Circuit Training (experimental) group ($n = 30$) increased from 1368 pounds to 1540 pounds over the course of the experiment. In other words, initially the Circuit Training group was weaker than the Structured Play group on the average. At the end of the experiment it was stronger.

Initially both boys' groups were statistically equal on summed strength values. They were compared with a t-test (39)

TABLE VI

ANALYSIS OF VARIANCE - BOYS - SUMMED STRENGTH VALUES

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F	Significant P=0.05
A Groups	615	1	615	.00289	
error a	12113692	57	212520		
B Trials	669311	1	669311	4.355	✓
AB Groups x Trials	14689	1	14689	.9558	
error b	875922	57	15367		
TOTALS	13674229	117			

Control Group - Before - O_1 - After - O_2
 Experimental Group- Before - $\bullet_1$ - After - $\bullet_2$

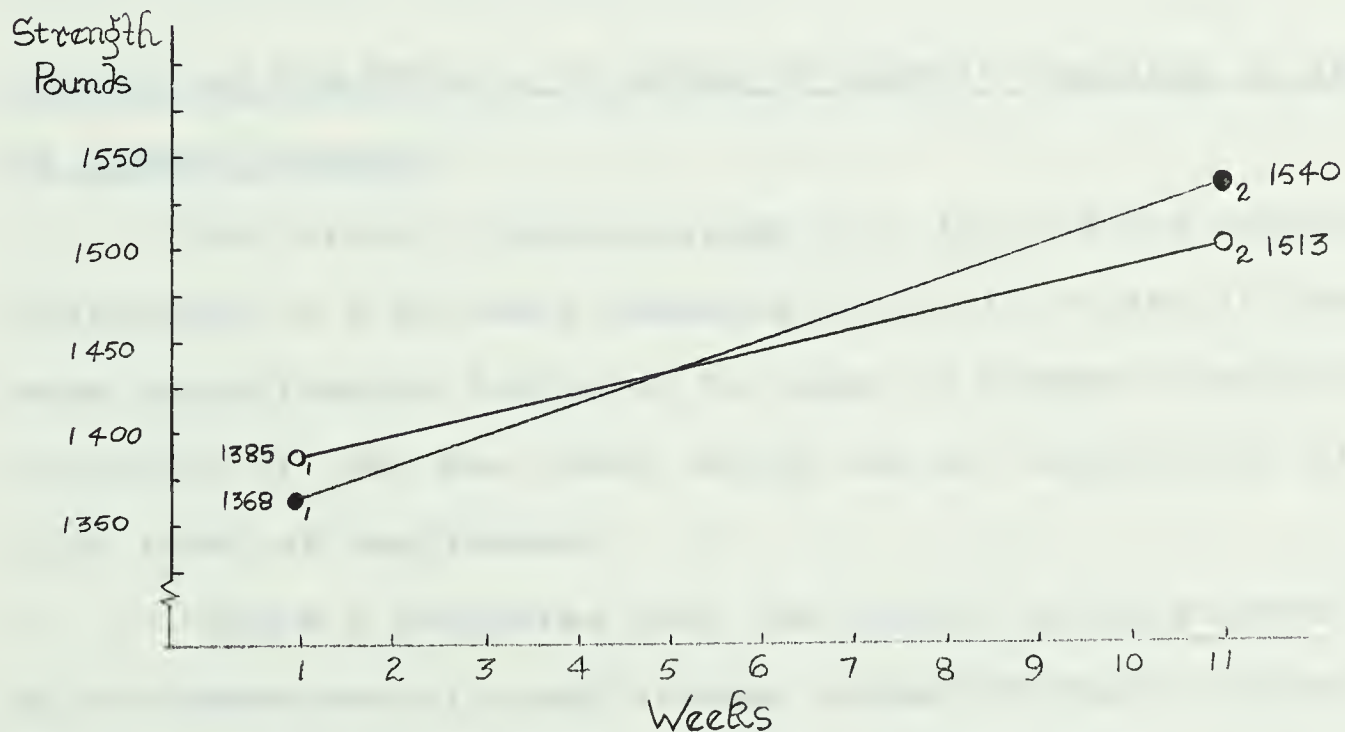


FIGURE 3

Comparison of mean strength values in pounds for Boys' Groups both Before and After the Circuit Training Program.

which resulted in a t-ratio of .199, a value not significant at the 0.05 level of confidence.

In testing strength scores for significance (Table VI) the only part of the analysis which proved to be significant was the Trials effect (4.335/4.010). The Groups effect and Groups by Trials effect were not statistically significant. The significant Trials effect would indicate that the initial combined mean of the experimental and control groups was significantly different from the final combined mean of these two groups. As no AB effect resulted, it must be assumed that both groups improved in strength over the course of the experiment, but that these strength changes were not significantly different from each other.

Results of the Effects on Girls of Circuit Training in Terms of Summed Strength.

The Circuit Training group (n = 18) and the Structured Play group (n = 20) were compared initially to see if they were significantly different in terms of summed strength values. A t-ratio of .467 was found, which was not significant at the 0.05 level of confidence.

Figure 4 indicates that the control group started ahead of the experimental group in mean summed strength values with an average of 1092 pounds compared to 1060 pounds. At the conclusion of the experiment the positions were reversed, with the experimental group mean value at 1246 pounds, while the control or Structured Play group trailed with a mean value of 1147 pounds.

Table VII shows only two F-ratio values significant, Trials (15.426/4.11) and Groups by Trials (4.736/4.11).

From this data it is reasonable to state that one or both girls' groups have changed significantly over the trials but that the Circuit Training group increased in strength to a significantly greater degree than the Structured Play group. The difference in these changes may be assumed to be due to the effects of Circuit Training.

Summary of Results for Boys and Girls in Terms of Oxygen and Strength.

In the cases of both boys and girls the Circuit Training groups increased their mean predicted maximal oxygen consumption values while the Structured Play groups decreased slightly over the course of the experiment.

There were significant Groups by Trials effects but no significant Groups effects in terms of oxygen consumption values for both sexes. A significant Trials effect in oxygen consumption values was noted only in the case of the boys' groups.

All groups for both sexes made strength gains over the course of the experiment, with experimental groups passing control groups in both instances. A significant Trials effect was noted for both sexes in strength values, but no significant Groups effects resulted. Only in the case of the girls did the experimental group change in a significantly different manner from the control group in summed strength values.

TABLE VII

ANALYSIS OF VARIANCE - GIRLS - SUMMED STRENGTH VALUES

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F	Significant P=0.05
A Groups	21553	1	21553	.355	
error a	2184594	36	60683		
B Trials	262906	1	262906	15.426	✓
AB Groups x Trials	80711	1	80711	4.736	✓
error b	613545	36	17042		
TOTALS	3163309	75			

Experimental Group - Before - ●₁ - After - ●₂

Control Group - Before - ○₁ - After - ○₂

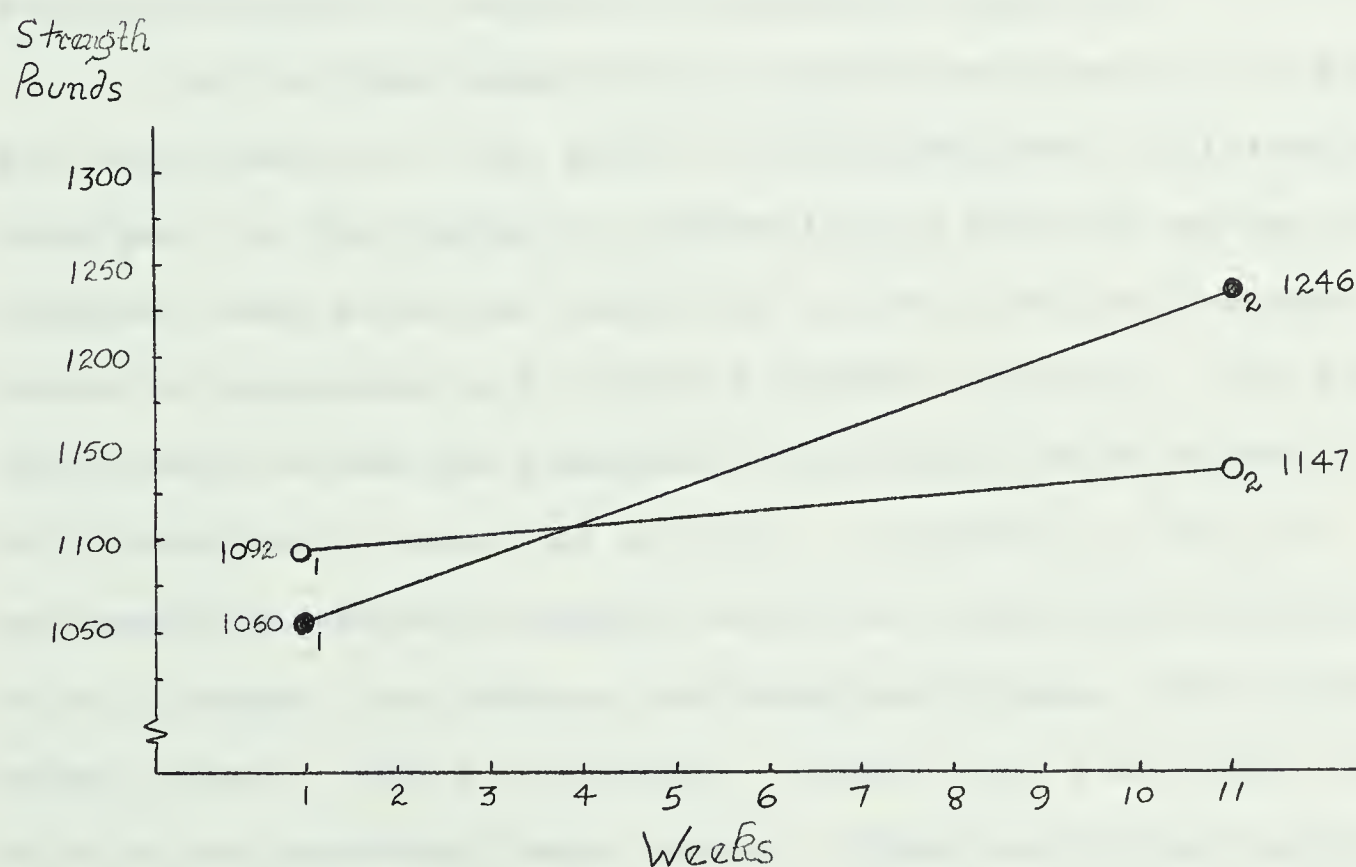


FIGURE 4

Comparison of mean strength values in pounds for Girls' Groups both Before and After the Circuit Training Program.

Discussion of Predicted Maximal Oxygen Consumption Results.

A number of questions arise in a review of the results of this study. Some of these questions will be presented below and possible answers given.

Why was there a decrease, although possibly insignificant, in the predicted maximal oxygen consumption of the Structured Play groups of both sexes?

It is known that body weight is related to maximal oxygen consumption (11, 77, 79, 88, 98) and that not until the age of twenty to thirty is there a drop off of aerobic capacity due to aging (6, 77). Why should growing, teenaged boys and girls suffer a reduction in aerobic capacity?

The ten week experimental period occurred in the fall and early winter. Just prior to the experiment, all subjects took part in four weeks of soccer in the physical education classes, each potential member of a group getting the same chance of exposure to a vigorous outdoor activity. All subjects were tested for placement into groups after exposure to this vigorously conducted activity. Therefore it may be assumed that aerobic capacity would be relatively high initially in all groups. As soon as the experiment began, the classes moved indoors, where volleyball, archery and a one-week introduction to basketball were taught. These activities were not conducted as strenuously as soccer. Also, with the coming of snow and cold, much outside, vigorous, random activity associated with summer and fall may have been reduced. The activity level common to all groups, then, may have been reduced due

to the types of activities presented in class and the effects of the transition to winter pastimes. The decreases may also have been statistically insignificant and due to the effects of random factors.

Why did the boys' groups achieve a significant Trials effect oxygen consumption F-ratio while the girls' groups did not?

This may be explained by the fact that the boys' study involved more subjects ($N = 60$) than the girls' ($N = 38$), therefore giving more degrees of freedom, smaller error terms, larger F-ratios and a greater chance for significance, other things being equal. A more powerful test of significance is possible with a greater number of subjects. In fact, the girls' Circuit Training group percentage gain over initial values in oxygen consumption was higher than that of the respective boys' group (10.26% to 7.44%). Also, the girls' control group decreased a greater average amount (-0.03 liters) than the boys' control group (-0.02 liters) over the course of the experiment.

Why were there no significant Groups effects resulting from the analysis of predicted maximal oxygen consumption values?

As has been pointed out at the beginning of this chapter, a marked change in scores obtained after the experiment compared to initial values would have been needed to bring about a significant Groups effect. A significant, but unmarked change in groups may be masked by the fact that initial,

statistically equal values for groups were considered in calculating the Groups effect. This was due to the fact that the groups were imperfectly equated prior to the experiment. As the Circuit Training Program was limited to between ten to twelve minutes per day, one would not be expected to achieve marked changes in oxygen consumption values over the ten week course of the experiment. The same reasoning would account for a lack of significant Groups effects in the analyses of boys' and girls' groups in terms of summed strength.

Discussion of Summed Strength Results.

Why were there strength increases for the Structured Play or control groups?

The obvious answer is that the Structured Play involved produced the strength changes. But the activities pursued (volleyball - five weeks, archery - four weeks, basketball - one week) were not primarily strength building in nature, with the possible exception of archery. The isotonic contractions involved in drawing an arrow and the isometric contractions involved in holding the aim may have produced some strength benefits. These effects may possibly have shown up in some of the readings that went into making up the final summed strength scores.

Another possible explanation would be the effects of maturation. The subjects were between the ages of thirteen and fifteen and there is evidence that from the beginning of puberty onward rapid gains in strength are made for both sexes (puberty comes between eleven and thirteen years for girls and

thirteen to fifteen years for boys) (24, 30, 43, 53, 55).

Why were the strength increases of the girls' Circuit Training group significantly greater than the gains of the girls' Structured Play group, while such was not the case for respective groups of boys? A number of answers are possible.

First, as is explained above, most of the girls would have completed the puberty stage and both girls' groups would be more apt to be stable in terms of strength development and therefore more likely to show any possible effects of Circuit Training. The boys in both groups were in the middle of the puberty stage and a greater random chance of a change due to maturation could possibly have made itself evident in both boys' groups. The boys' groups would be more naturally variable and less likely to show any effects of a limited Circuit Training Program.

Second, an observation based on experience is that girls tend to be more conscientious than boys and more willing to work consistently hard at the circuits than the boys. This was thought to be the case with the performance on the experimental Circuit Training Program.

Third, it is generally believed by weight lifters that strength is built most effectively through lifting very heavy weights a few repetitions (25, 64), between three to five times, for example. The weights employed in the weight circuit were designed to be lifted at a maximum rate of between twelve and twenty-four times. This has a tendency, in theory, to

develop more muscular endurance than strength. Nevertheless, with girls being weaker than boys, there would be a greater chance that the weights, being relatively more difficult for the girls to handle, might have produced a greater strength effect in girls.

Discussion of Motivation on the Circuit.

In justifying this study, it was pointed out that Circuit Training frees the teacher from direct, active participation in conducting the fitness program. This is an important practical consideration for any teacher who may have seven or eight classes arriving one after another daily. Keeping in mind that the circuits are done by each pupil on his or her own volition, motivation to have each individual do the exercises honestly becomes an important concern. Short Circuiting (see definition, Chapter I) becomes a problem. For the conscientious student, performance of the circuits in an honest, vigorous, enthusiastic manner becomes a challenge. Perseverance and determination build self-esteem. But for the less conscientious, Short Circuiting is the easy way out and the program becomes a daily exercise in dishonesty. Certainly our schools are not intended to teach that dishonesty pays. It is, therefore, necessary that the teacher be alert to and concerned about this problem. This constant alertness and concern may have a tendency to be more of a strain for the teacher than actually leading students through tables of exercises. The limitations of such tables, however, should be patently obvious to any experienced teacher.

The only solutions that appear to have merit are extensions of the devices to maintain motivation as outlined in Chapter III. In brief, these may be summarized into an appeal to the reason and understanding of the pupils, recognition and reward for excellence of performance, and variety in activity. It is felt that variety in activity holds the most promise. Circuit Training in its various forms should be alternated with other fitness programs such as Parlauf running, obstacle courses, relay games or combative competitions. Devising such programs suitable for the junior high school level remains a challenge to enthusiastic, creative teachers who may be blessed with time just to sit on occasion and think about where education is going and how it should proceed.

Discussion of the Results of this Study in Comparison to Other Circuit Training Studies.

There is only one study known to have been done comparable to this study on school children in an actual operational setting involving the use of controls. Brown (21) reported no significant difference between experimental and control groups in which the experimental group did Circuit Training three times a week, ten minutes per session as part of the regular physical education classes. The control group carried on with regular physical education class activities. Subjects were Grade Five girls and the fitness test was the A.A.H.P.E.R. Youth Fitness Test. The fact that the Circuit Training in the present study was associated with significantly different changes between experimental and control groups in oxygen

consumption values for both sexes and in strength values for girls may be explained. Circuit Training was performed over a ten week period, five days per week in the present study and for only an eight week period, three times per week in Brown's study.

The study reported by Adamson and Morgan (4:85) showed percentage increases in exercises repetitions involving strength for fifteen year old boys, but no controls were reported. Without controls, it does not seem possible to ascribe strength increases wholly to Circuit Training, particularly in the light of the strength increases made by the boys' control group in the present study. Subjects were of about the same age in both studies.

Chapter II presented findings of studies done at the university level in which Circuit Training proved effective (2, 51, 67, 71, 93). In the three studies reported involving the use of controls in which physical fitness was measured; subjects performed the circuits only twice a week, but for from twenty to thirty-five minutes per session (51, 67, 93). Subjects were relatively mature university students. It is difficult to compare the results of these studies with the present study in which relatively immature junior high school pupils performed a limited program of about ten minutes per session for five days per week.

Finally, a comment on the school of thought that advocates the importance of cardiovascular fitness, Cureton (33:33) being a chief proponent.

We must teach what I consider to be the basic process. That is a steady rhythmical training which lasts thirty minutes or longer. This repeated day after day after day, getting steadily harder but very gradually. The average citizen of this country has no idea of this basic process -- we must teach him.

The performance of Circuit Training in the present study did produce statistically significant cardio-vascular effects as measured by the Astrand-Ryhmig nomogram. The effects were achieved by repeated training sessions for ten weeks at five days per week. The sessions were not thirty minutes in duration or longer but only ten to twelve minutes in length. The Circuit Training involved may not be considered steady and rhythmical, but rather of a very strenuous nature over short session durations.

The relative merits of both techniques are left open to further investigation. No doubt from a practical point of view, a physical education teacher might be pleased to know that he may be able to achieve some cardio-vascular fitness effects in his classes, yet still have time to teach skills for use in leisure periods.

It will be noted that results of the present study also indicated statistically significant strength effects caused by the limited program of Circuit Training in the case of girls. The boys' experimental group also made greater strength gains than the control group. Although these changes were not significantly different from each other, one might speculate that, had the boys been better motivated, and/or used heavier weights, this trend might also have been significant.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary.

The purpose of this study was to investigate the effects of a program of Circuit Training on selected strength and cardiovascular measures. The program was administered over a ten week period, five days per week for from ten to twelve minutes per day in which ~~from~~ two to three circuits per individual were performed. Grade Eight and Grade Nine boys (N = 60) and girls (N = 38) were used as subjects. Cardiovascular endurance was measured by the Astrand-Ryhming (10) predicted maximal oxygen intake test with values given in liters per minute. Muscular strength was measured by cable tensiometer and grip dynamometer techniques after the methods used by Howell, Loiselle and Lucas (53). Each individual's strength scores were summed to give a single strength index in pounds.

Boys and girls were treated separately on both of the indices employed and each sex had an experimental group which performed Circuit Training and a control group which performed Structured Play instead as part of the daily physical education class period.

Groups within sexes were achieved by use of a modification of the block method (82:297). Within each sex, subjects were arrayed on strength values and the array divided into quartiles. Within each strength quartile, individuals were

again arrayed according to oxygen values. Individuals were paired within each of these oxygen arrays beginning with the two lowest scores and progressing upward to the highest scores. Each individual in an oxygen pair was then assigned randomly to one or another of two groups for each sex. Groups in each sex were assigned randomly to be either experimental or control. The result of this process was two imperfectly equated groups (experimental and control) on two variables (oxygen consumption and strength) for each sex.

The groups within each sex were tested by a two-tailed test of t (39) on each variable to ensure that they were not significantly different from each other prior to the Circuit Training Program. No significant differences were found between groups within sexes on either variable at the 0.05 level of confidence.

In the case of each sex, experimental groups did ten to twelve minutes of Circuit Training during each class period. Control groups played or practiced the activity being learned in the physical education classes (Structured Play) for the same length of time. Otherwise, class activities of both groups were kept constant.

The Circuit Training included two-arm curls, dumbbell swings, bench presses, squats, two arm presses and bench jumps, all performed with weights. Weights were selected so as to be lifted at a maximum rate of between twelve and twenty-four times. A second circuit employed involved chins, knee-bends, push-ups, sit-ups, bench jumps and skips. No weights were

used here. A third circuit consisted of running laps around the gymnasium floor. Appendix D includes diagrams of each exercise used in the circuits. Students in the experimental groups performed a different one of the above circuits each day through a three day cycle. The Structured Play groups performed in volleyball, archery and basketball instead.

An analysis of variance as outlined by Edwards (37:227) was used to determine significance in Groups effects, Trials effects and Groups by Trials effects for experimental and control groups compared before and after the experiment on both oxygen consumption and strength values.

The following variance sources showed significant F-ratios at the 0.05 level of confidence:

1. Boys' groups in predicted maximal oxygen consumption values in liters per minute -- Trials effect and Groups by Trials effect. The experimental group mean increased from 2.42 to 2.60 liters per minute while the control group mean decreased from 2.35 to 2.33 liters per minute.

2. Girls' groups in predicted maximal oxygen consumption values in liters per minute -- Groups by Trials effect. The experimental group mean increased from 1.95 to 2.15 liters while the control group mean decreased from 1.84 to 1.81 liters per minute.

3. Boys' groups in summed strength values in pounds -- Trials effect. The experimental group mean increased from 1368 to 1540 pounds while the control group mean also increased from 1385 to 1513 pounds.

4. Girls' groups in summed strength values in pounds -- Trials effect and Groups by Trials effect. The experimental group summed strength mean increased from 1060 to 1246 pounds while the control group mean increased from 1092 to 1147 pounds.

Conclusions.

The following conclusions appear to be reasonable within the limitations of the samples investigated, the cardiovascular and strength measurements employed, the types and performance of the Circuit Training employed, and the statistical treatments used:

1. Circuit Training influenced the boys' experimental group to change in a significantly different way than the boys' control group in terms of predicted maximal oxygen consumption. The experimental group mean increased while the control group mean decreased.

2. Circuit Training influenced the girls' experimental group to change in a significantly different way than the girls' control group in terms of predicted maximal oxygen consumption. The experimental group mean increased while the control group mean decreased.

3. The boys' experimental group did not change in a significantly different way than the boys' control group in terms of summed strength values. The means of both groups increased, but the mean of the experimental group increased more than the mean of the control group.

4. Circuit Training influenced the girls' experimental

group to change in a significantly different way than the girls' control group in terms of summed strength values. The means of both groups increased, but the mean of the experimental group increased more than the mean of the control group.

5. Significant Trials effects were achieved in comparisons involving boys' groups as well as girls' groups on summed strength values and boys' groups on predicted maximal oxygen consumption values. In each case, experimental groups had final mean values that were higher than respective control groups.

6. No significant Trials effect was achieved in the comparison involving girls' groups on predicted maximal oxygen consumption values. The experimental groups' mean increased, while the control groups' mean decreased over the course of the experiment.

7. No significant Groups effects were achieved by either sex on either variable.

Differences were examined for significance at the 0.05 level of confidence.

Recommendations.

1. A variety of physical fitness programs suited for use at the secondary school level should be developed. These programs should be relatively easy to administer; involve the elements of fun and competition; require the use of some interesting but inexpensive equipment; allow for individual differences; not tax the finite energy of the teacher, and be generally educationally sound.

Such programs may then be alternated with Circuit Training to help maintain the enthusiasm, honesty and vigor in participation needed to achieve desirable significant effects in a limited time.

2. Further studies might be carried out over longer periods of time so that the effects of Circuit Training and de-training can be studied. Heavier weights might be used.

BIBLIOGRAPHY

1. Adams, F. H., Linde, L. M., Hisazumi, M., "The Physical Working Capacity of Normal School Children". Pediatrics, vol. 28 (1961), pp. 55-64
2. Adamson, G. T., "Circuit Training", Journal of Physical Education, vol. 46 (March, 1954), p. 6.
3. Adamson, G. T., "Circuit Training", The Physical Educator vol. 13 (May, 1956), pp. 68-70.
4. Adamson, G. T., Morgan, R. E., "Circuit Training for School Boys", Journal of Physical Education, vol. 46 (Nov., 1954), pp. 84-91.
5. American Association for Health, Physical Education and Recreation, "Fitness for Youth", Journal of Health, Physical Education and Recreation, vol. 27 (Dec., 1956).
6. Astrand, I., "Aerobic Work Capacity in Men and Women with Special Reference to Age", Acta Physiologica Scandinavica, vol. 49 (1960), Suppl. 169.
7. Astrand, I., "The Physical Work Capacity of Workers 50-64 Years Old", Acta Physiologica Scandinavica, vol. 42 (1958), pp. 73-86.
8. Astrand, I., Astrand, P.-O., and Hedman, R., "Circulatory and Respiratory Adaptation to Severe Muscular Work", Acta Physiologica Scandinavica, vol. 50 (1960), 294-299.
9. Astrand, I., Astrand, P.-O., Rodahl, Kaare, "Maximal Heart Rate During Work in Older Men", Journal of Applied Physiology, vol. 14 (1959), 562-563.
10. Astrand, P.-O., Pyhming, I., "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work", Journal of Applied Physiology, vol. 7 (1954), pp. 218-221.
11. Astrand, P.-O., Experimental Studies of Physical Working Capacity in Relation to Sex and Age, Copenhagen: Munksgaard, 1952, pp. 23-37; 110; 148.
12. Astrand, P.-O., "Human Physical Fitness with Special Reference to Age and Sex", Physiological Reviews, vol. 36 (1956), pp. 307-335.
13. Astrand, P.-O., "Maximum Working Capacity for the Two Sexes and for Different Age Groups From 41 to 30 Years", Acta Physiologica Scandinavica, vol. 25 (Supplementum 89, 1951), pp. 3-4.

14. Astrand, P.-O., Work Tests with the Bicycle Ergometer, Varberg, Sweden, 1965.
15. Baycroft, G. H., "An Evaluation of the Modified Astrand-Ryhming Nomogram as an Estimator of Maximal Oxygen Consumption", Unpublished Master's Thesis, University of Alberta, 1964.
16. Bengtsson, E., "The Working Capacity in Normal Children Evaluated by Submaximal Exercise on the Bicycle Ergometer and Compared with Adults", Acta Medica Scandinavica, vol. 154 (1956), pp. 91-109.
17. Bill C-131, An Act To Encourage Fitness and Amateur Sport, Federal Government of Canada, Ottawa.
18. Bock, A. V., Van Caulaert, C., Dill, D.B., Folling, A., Hurxthal, L. M., "Studies in Muscular Activity. III Dynamical Changes Occurring in Man at Work", Journal of Physiology, vol. 66 (1928), pp. 136-161.
19. Bookwalter, K. W., "Grip Strength Norms for Males", Research Quarterly, vol. 21 (1950), pp. 249-273.
20. Borg, G., Dahlstrom, M., "The Reliability and Validity of a Physical Work Test", Acta Physiologica Scandinavica, vol. 55 (1962), pp. 353-361.
21. Brown, Annie May, "The Effect of Circuit Training on the Physical Fitness of Grade 5 Girls", Unpublished Master's Thesis, University of British Columbia, 1961.
22. Buskirk, E., Taylor, H. L., "Maximal Oxygen Intake and its Relation to Body Composition with Special Reference to Chronic Physical Activity and Obesity", Journal of Applied Physiology, vol. 11 (1957), pp. 72-78.
23. Buskirk, E., "Relationship in Man Between the Maximal Oxygen Intake and Components of Body Composition", Unpublished Doctoral Thesis, University of Minnesota, December, 1953.
24. Buxton, Doris, "Extension of the Kraus-Weber Test", Research Quarterly, vol. 28 (1957), pp. 210-217.
25. Capen, E., "Study of Four Programs of Heavy Resistance Exercise for Development of Muscular Strength", Research Quarterly, vol. 27 (May, 1956).
26. Clarke, H. H., A Manual: Cable Tension Tests, Springfield College, Springfield.
27. Clarke, H. H., Carter, G. H., "Oregon Simplification of

- the Strength and Physical Fitness Indices", Research Quarterly, vol. 30 (1959), pp. 3-10.
28. Cowell, C. C., Hazelton, H., Curriculum Designs in Physical Education, New York: Prentice Hall, Inc., 1955, p. 65.
 29. Coyne, L. L., "The Relationship of Maximal Oxygen Intake to Body Composition and Total Body Weight in Active Males", Unpublished Master's Thesis, University of Alberta, Edmonton, August, 1963.
 30. Cullumbine, H., Bibile, S. W., Wikramanavake, T. W., Watson, R. S., Influence of Age, Sex, Physique and Muscular Development on Physical Fitness", Journal of Applied Physiology, vol. 2 (1950), pp. 488-511.
 31. Cumming, C. R., Danziger, R., "Validity of Pulse Rate Determination of Working Capacity", Pediatrics, vol. 32 (1963), pp. 202-208.
 32. Cureton, T. K., Physical Fitness Appraisal and Guidance, St. Louis: The C. V. Mosby Company, 1947.
 33. Cureton, T. K., "Putting Fitness into Physical Education", Journal of C.A.H.P.E.R., vol. 29 (Oct.-Nov., 1962), p. 21.
 34. Dempsey, J. A., "The Prediction of Basal and Maximal Oxygen Consumption from Various Body Measurements," Unpublished Master's Thesis, University of Alberta, Edmonton, August, 1963.
 35. de Vries, H. A., Klafs, C. E., "Prediction of Maximal Oxygen Intake from Submaximal Tests", Physiology of Exercise Laboratory, Long Beach, California, March, 1964.
 36. Edwards, A. L., Experimental Design in Psychological Research, Toronto: Holt, Rinehart and Winston, 1964, pp. 227.
 37. Erickson, L., Simonson, E., Taylor, H. L., Alexander, H., Keys, A., "The Energy Cost of Horizontal and Grade Walking on the Motor Driven Treadmill", American Journal of Physiology, vol. 145 (1946), p. 391.
 38. Espenschade, Anna S. "Motor Performance in Adolescence, Including the Study of Relationships with Measures of Physical Growth and Maturity", Monograph of the Society for Research and Child Development, vol. 5(1) (1940), pp. 1-126.
 39. Ferguson, G. A., Statistical Analysis in Psychology and

Education, Toronto: McGraw-Hill Book Company, Inc., 1959, p. 136.

40. Fleishman, E. A., Examiner's Manual for the Basic Fitness Tests, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964. 60 pp.
41. Glassford, R. G., "A Comparison of Maximal Oxygen Consumption Values as Determined by Predicted and Actual Techniques", Unpublished Master's Thesis, University of Alberta, Edmonton, 1964.
42. Green, H. J., "A Comparison of the Work Capacity of the Urban and Rural Secondary School Populations in the Province of Alberta as measured by the Astrand Submaximal Bicycle Ergometer Test", Unpublished Master's Thesis, University of Alberta, Edmonton, 1965.
43. Hall, D. M., "Selection and Standardization of Strength Tests for 4-H Club Members", Research Quarterly, vol. 27 (1956), pp. 285-300.
44. Hettinger, T., Birkhead, N. C., Howath, S. M., Issekutz, B., Rodahl, K., "Assessment of Physical Work Capacity", Journal of Applied Physiology, vol. 16 (1961), pp. 153-156.
45. Hodgson, J. L., "The Effect of Circuit Training and Isometric Exercise on Treadmill Performance", Unpublished Master's Thesis, University of Alberta, 1963.
46. Howell, M. L., Morford, W. R., "A Home Fitness Plan", Health, vol. 29 (June, 1961), pp. 22-23, 40-41.
47. Howell, M. L., Morford, W. R., "Circuit Training", Journal of Health, Physical Education and Recreation, vol. 32 (Nov., 1961), pp. 33-35.
48. Howell, M. L., Morford, W. R., "Circuit Training, available in mimeographed form, University of Alberta, Edmonton, 1961.
49. Howell, M. L., Morford, W. R., "Circuit Training for a College Fitness Program", Journal of Health, Physical Education and Recreation, vol. 35 (Feb., 1964), pp. 30-31, 72-73.
50. Howell, M. L., Morford, W. R., "Circuit Training for Secondary Schools", Journal of the Canadian Association for Health, Physical Education and Recreation, vol. 26 (June-July, 1960), pp. 12-13, 15.
51. Howell, M. L., Hodgson, James, Alexander, J. A., Bjornson, D., Richardson, J. R., "Effects of Circuit Training

on Strength and Muscular Endurance", University of Alberta, 1962.

52. Howell, M. L., Hodgson, J. L., Sorenson, J. M., "The Effect of Circuit Training on the Modified Harvard Step Test", University of Alberta, 1962.
53. Howell, M. L., Loiselle, Denise S., Lucas, W. Geoffery, Strength of Edmonton School Children, Fitness Research Unit, University of Alberta.
54. Hyde, R. C., "The Astrand-Ryhming Nomogram as a Predictor of Aerobic Capacity for Secondary School Students", Unpublished Master's Thesis, University of Alberta, Edmonton, 1965.
55. Jones, H. E., Motor Performance and Growth. A developmental Study of Static Dynamometric Strength. Berkely, University of California Press, 1949, 181 pp.
56. Jones, H. E., "The Sexual Maturing of Girls as Related to Growth in Strength", Research Quarterly, vol. 18 (1947), pp. 135-143.
57. Karpovich, P. V., Physiology of Muscular Activity, London: W. B. Saunders Company, 1959.
58. Knehr, C. A., Dill, D. B., Neufeld, W., "Training and its Effects on Man at Rest and at Work", American Journal of Physiology, vol. 136 (1942), p. 148.
59. Krogh, A., Lindhard, J., "A Comparison Between Voluntary and Electrically Induced Muscular Work in Man", Journal of Physiology, vol. 51 (1917), pp. 182-201.
60. Krogh, A., Lindhard, J., "The Relative Values of Fats and Carbohydrates as Sources of Muscular Energy", Biochemical Journal, vol. 14 (1920), p. 29.
61. Lange Anderson, K., Respiratory Recovery from Muscular Exercise of Short Duration, Oslo: Oslo University Press, 1959, pp. 45.
62. Larsson, Y., Persson, B., Sterky, G., Thoren, C., "Functional Adaptation to Rigorous Training and Exercise in Diabetic and Non-Diabetic Adolescents", Journal of Applied Physiology, vol. 19 (1964), pp. 629-635.
63. Lundgren, N. P. V., "The Physiological Effects of Time Schedule Work on Lumber-Workers", Acta Physiologica Scandinavica - Supplementum 13, vol. 41 (1946), pp. 1-137.
64. MacQueen, I. J., "Recent Advances in the Technique of

- Progressive Resistance Exercise", British Medical Journal, vol. 2, 1954, pp. 1193-1198.
65. Methany, E., Brouha, L., Johnson, R. E., Farbes, W. H., "Some Physiologic Responses of Women and Men to Moderate and Strenuous Exercise: A Comparative Study", American Journal of Physiology, vol. 137 (1942), pp. 318-326.
 66. Mitchell, J. M., Sproule, B. J., and Chapman, C. B., "The Physiological Meaning of the Maximal Oxygen Intake Test", Journal of Clinical Investigation, vol. 38 (1958), pp. 538-547.
 67. Monaghan, J. S., "The Effects of Circuit Training on Physical Fitness", Unpublished Graduation Essay, University of Alberta, 1962.
 68. Morgan, R. E., Adamson, G. T., Circuit Training, London: G. Bell and Sons, Ltd., 1957.
 69. Newton, J. L., "The Assessment of Maximal Oxygen Intake", The Journal of Sports Medicine and Physical Fitness, vol. 3 (1963), pp. 164-169.
 70. Norman, R. W. K., "Age Differences in the Work Capacity of Alberta Secondary School Students as Measured by the Astrand Predicted Maximal Oxygen Intake Test", Unpublished Master's Thesis, University of Alberta, Edmonton, 1966.
 71. Nunney, Derek, N., "Relation of Circuit Training to Swimming", Research Quarterly, vol. 31 (May, 1960), pp. 188-198.
 72. Perry, Jack, "A Proposed Program of Physical Education for Boys in Alberta Junior High Schools", Unpublished Master's Thesis, University of Alberta, Edmonton, 1953.
 73. Phillips, Marjorie, "Analysis of Results from the Kraus-Weber Test of Minimum Muscular Fitness in Children", Research Quarterly, vol. 26 (1955), pp. 314-323.
 74. R.C.A.F., 5BX Plan for Physical Fitness, Queen's Printer and Controller of Stationery, Ottawa, 1958.
 75. Rodahl, K., Issekutz, B., Jr., Muscle as a Tissue, Rodahl and Horvath, Ed., Toronto: McGraw Hill Book Co., 1962.
 76. Rodahl, K., Astrand, P.-O., Birkhead, N., Hettinger, T., Issekutz, B., Jr., Jones, M., Weaver, R., "Physical Work Capacity", American Medical Association Archives Environmental Health, vol. 2 (1961), pp. 499-510.
 77. Robinson, S., "Experimental Studies of Physical Fitness

- in Relation to Age", Arbeitsphysiologie, vol. 10 (1938), pp. 251.
78. Robinson, S. "Metabolic Adaptations to Exhausting Work as Affected by Training", American Journal of Physiology, vol. 133 (1940), p. 428.
 79. Robinson, S., Edwards, H. T., Dill, D. B., "New Records in Human Power", Science, vol. 85 (1939), pp. 401-410.
 80. Rowell, L. B., Taylor, H. L., Wang, Y., "Limitations of Prediction of Maximal Oxygen Intake", Journal of Applied Physiology, vol. 19:5 (1964), pp. 919-927.
 81. Schrecker, K. A., "Physical Fitness", Journal of Physical Education, vol. 46 (July, 1954), p. 55.
 82. Scott, M. G., Research Methods in Health, Physical Education and Recreation, Washington, D.C., American Association for Health Physical Education and Recreation, 1959.
 83. Sjostrand, T., "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works", Acta Medica Scandinavica, Supple. 196 (1947), pp. 687-699.
 84. Taylor, Bryce, M., "The Effects of Certain Fitness Programs Upon the Cardio-Vascular and Muscular Status of Business Men", Unpublished Master's Thesis, University of British Columbia, 1961.
 85. Taylor, C., "Effect of Work-Load and Training on Heart Rate", American Journal of Physiology, vol. 135 (1941) pp. 27-42.
 86. Taylor, Craig, "Some Properties of Maximal and Submaximal Exercise with Reference to Physiological Variation and the Measurement of Exercise Tolerance", American Journal of Physiology, vol. 162 (1944), pp. 200-212.
 87. Taylor, H. L., Buskirk, E., Henschel, A., "Maximal Oxygen Intake as an Objective Measure of the Cardio-Respiratory Performance", Journal of Applied Physiology, vol. 8 (1955), pp. 73-80.
 88. Taylor, H. L., Wang, Y., Bowell, L., Blomquist, G., "The Standardization and Interpretation of Submaximal and Maximal Tests of Working Capacity", Pediatrics, vol. 32 supplement (Oct., 1963), pp. 703-722.
 89. Torpey, J. E., "Strength Tests for Young Children - A Pilot Study", Research Quarterly, vol. 31 (1960), pp. 238, 239.
 90. Van Vliet, M. L., Physical Education for Junior and Senior

High Schools, Toronto: The MacMillan Company of Canada Limited, 1956.

91. Wahlund, H. G., "Determination of the Physical Working Capacity: A Physiological and Clinical Study with Special Reference to Standardization of Cardiopulmonary Function Tests", Acta Medica Scandinavica, vol. 132 (1948), Suppl. 215.
92. Watt, Norman S., "Application of Circuit Training to Developmental Physical Education", Physical Fitness Newsletter, University of Oregon, series VI, no. 9 (May, 1960), pp. 1-6 (mimeographed).
93. Watt, N. S., "The Comparison of Two Methods of Physical Fitness Training in Low Fitness Males at the University of Oregon", Unpublished Master's Thesis, University of Oregon, 1961 (microcarded).
94. Welch, B. E., Riendeau, P., Crisp, C. E., Isenstein, R.S., "Relationships of Maximal Oxygen Consumption to Various Components of Body Composition", Journal of Applied Physiology, vol. 12 (1958), pp. 395-398.
95. Willgoose, Carl E., "Physical Fitness - Our Primary Objective", Journal of Health, Physical Education and Recreation, vol. 30 (Nov., 1959), p. 33.
96. Williams, C. G., Bredell, G. A. G., Wyndham, C. H., Strydom, N. B., Morrison, J. F., Peter, J., Fleming, P. W., Ward, J. S., "Circulatory and Metabolic Reactions to Work in Heat", Journal of Applied Physiology, vol. 17 (1962), pp. 625.
97. Wyndham, C. H., Ward, J. S., "An Assessment of the Exercise Capacity of Cardiac Patients", Circulation, vol. 16 (1957), pp. 384-93.
98. Wyndham, C. M., Strydom, N. B., Maritz, J. S., Morrison, J. F., "Intake and Maximal Heart Rate During Strenuous Work", Journal of Applied Physiology, vol. 14 (1959) pp. 927-936.

APPENDICES

STATISTICAL TREATMENT

In effect, four studies were carried out, an oxygen and a strength study for boys and again for girls. Statistical procedures are given for one sex only, i.e. the girls. The same procedures were carried out for boys.

Study Design

1. All female subjects ($n = 38$) were tested for predicted maximal oxygen consumption values in liters per minute and summed strength values in pounds. This was done prior to when the experiment began.
2. An array of subjects on strength values was performed and subdivided into quartiles.
3. Each strength quartile was re-arrayed according to oxygen values of the subjects therein. The result was four arrays based on oxygen values.
4. Subjects in oxygen arrays were paired beginning with the two subjects with lowest oxygen values and ending with subjects with highest oxygen values.
5. Members of each pair were assigned by a toss of a coin into one or another of two groups.
6. Resulting groups were assigned by a toss of a coin to experimental (Circuit Training) or control (Structured Play).

Two Tailed Test of t

Experimental and control groups were compared on each variable (oxygen and strength) to determine if groups represented a common population in each variable. Procedures for the t test (39) in each variable were identical. Only steps

used for girls' oxygen groups will be presented below. Table VIII contains the data from which the calculations were made.

e_1 -- experimental group before experiment.

c_1 -- control group before experiment.

n_1 -- number of subjects in experimental group.

n_2 -- number of subjects in control group.

x_1 -- a score of a subject in experimental group.

x_2 -- a score of a subject in control group.

$\bar{X}_1$ -- mean of scores in experimental group.

$\bar{X}_2$ -- mean of scores in control group.

$\sum$ -- sum.

s^2 -- variance.

DF -- degrees of freedom = $n_1 + n_2 - 2$.

1. Each group's oxygen values were summed and averaged.

$$\sum e_1 = 35.15$$

$$\sum c_1 = 36.80$$

$$\bar{X}_1 = 1.96$$

$$\bar{X}_2 = 1.84$$

2. The difference of each score in a group from the mean of the group was calculated, squared and summed.

$$\sum (x_1 - \bar{X}_1)^2 = 1.6075$$

$$\sum (x_2 - \bar{X}_2)^2 = 2.4270$$

3. s^2 was calculated by adding $\sum (x_1 - \bar{X}_1)^2$ and $\sum (x_2 - \bar{X}_2)^2$ and dividing by the degrees of freedom.

$$\frac{1.6075 + 2.4270}{36} = .1120 = s^2$$

4. The t ratio was calculated from the following formula:

TABLE VIII

DATA FOR t TEST AND ANALYSIS OF VARIANCE OF GIRLS OXYGEN VALUES

S	e_1	e_1^2	e_2	e_2^2	S	$(e_1 + e_2)^2$
1	1.90	3.6100	2.05	4.2025	1	15.6025
2	1.50	2.2500	1.80	3.2400	2	10.8900
3	1.60	2.5600	1.80	3.2400	3	11.5600
4	1.40	1.9600	1.85	3.4235	4	10.5625
5	1.80	3.2400	2.40	5.7600	5	17.6400
6	2.30	5.2900	3.00	9.0000	6	28.0900
7	1.50	2.2500	1.70	2.8900	7	10.2400
8	2.20	4.8400	2.76	7.6176	8	24.6016
9	2.00	4.0000	1.95	3.8025	9	15.6025
10	2.00	4.0000	2.20	4.8400	10	17.6400
11	2.70	7.2900	2.73	7.4529	11	29.4849
12	2.55	6.5025	2.65	7.0225	12	27.0400
13	2.00	4.0000	1.98	3.9204	13	15.8404
14	2.05	4.2025	2.00	4.0000	14	16.4025
15	1.90	3.6100	2.10	4.4100	15	16.0000
16	2.20	4.8400	2.15	4.6225	16	18.9225
17	1.80	3.2400	1.60	2.5600	17	11.5600
18	1.75	3.0625	2.00	4.0000	18	14.0625
T	35.15	70.7475	38.72	86.0034	T	311.7419

S	C_1	C_1^2	C_2	C_2^2	S	$(C_1 + C_2)^2$
1	1.90	3.6100	1.25	1.5625	1	9.9225
2	1.40	1.9600	1.40	1.9600	2	7.8400
3	1.45	2.1025	1.55	2.4025	3	9.0000
4	1.40	1.9600	1.30	1.6900	4	7.2900
5	1.75	3.0625	2.00	4.0000	5	14.0625
6	1.85	3.4225	1.92	3.6864	6	14.2124
7	1.95	3.8025	2.20	4.8400	7	17.2225
8	1.80	3.2900	1.65	2.7225	8	11.9025
9	1.65	2.7225	1.55	2.4025	9	10.2400
10	1.75	3.0625	1.58	2.4964	10	11.0889
11	2.35	5.5225	1.82	3.3124	11	17.3889
12	1.60	2.5600	2.05	4.2025	12	13.3225
13	2.65	7.0225	2.78	7.7284	13	29.4849
14	2.30	5.2900	2.30	5.2900	14	21.1600
15	2.20	4.8900	1.93	3.7249	15	17.0569
16	1.30	1.6900	0.95	.9025	16	5.0625
17	1.50	2.2500	1.40	1.9600	17	8.4100
18	2.05	4.2025	2.01	4.0401	18	16.4836
19	2.05	4.2025	2.20	4.8400	19	18.0625
20	1.90	3.6100	2.30	5.2900	20	17.6400
T	36.80	70.1350	36.14	69.0536	T	276.8536

 e_1 - Experimental Group Before e_2 - Experimental Group After C_1 - Control Group Before C_2 - Control Group After

S - Subjects

T - Totals

 $\bar{X}_1$ - Mean Experimental Group
Before = 1.95 $\bar{X}_2$ - Mean Control Group
Before = 1.84

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S^2}{n_1} + \frac{S^2}{n_2}}} = \frac{1.95 - 1.84}{\sqrt{\frac{.1120}{18} + \frac{.1120}{20}}} = \frac{.11}{\sqrt{.0118}} = \frac{.11}{.1086} = 1.0128$$

5. The t value was entered into a Table of t (39) at 36 degrees of freedom and found not large enough to indicate significance at the .05 level of confidence (t value required for significance = 2.042).

Analysis of Variance

An analysis of variance as outlined by Edwards (36:227) was used to test for significance between Groups, between Trials and between Groups over Trials. Procedures for resulting F ratio tests for each sex on each variable were identical. Only the results of the girls' oxygen experiment will be analyzed as an example. Table VIII gives data from which example calculations were made. The following is a key to some of the symbols used with corresponding example values in brackets where applicable:

e_1 = score(s) of a subject(s) experimental group, before.

e_2 = score(s) of a subject(s) experimental group, after.

c_1 = score(s) of a subject(s) control group, before.

c_2 = score(s) of a subject(s) control group, after.

Σ = sum.

G or Σe_1 = sum of scores, experimental group, before. (35.15)

H or Σc_1 = sum of scores, control group, before. (36.80)

I or Σe_2 = sum of scores, experimental group, after. (38.72)

J or Σc_2 = sum of scores, control group, after. (36.14)

K or Σe_1^2 = sum of squared scores, experimental group before.
(70.7475)

- L or $\sum c_1^2$ = sum of squared scores, control group, before.
(70.1350)
- M or $\sum e_2^2$ = sum of squared scores, experimental group, after.
(86.0034)
- P or $\sum c_2^2$ = sum of squared scores, control group, after.
(69.0536)
- Q or $\sum (e_1 + e_2)^2$ = sum of squared value of each subjects totaled
before and after score, experimental group.
(311.7419)
- R or $\sum (c_1 + c_2)^2$ = sum of squared value of each subjects totaled
before and after score, control group.
(276.8536)

TSS = Total Sum of Squares.

SSS = Sum of Squares for Subjects.

SST = Sum of Squares for Trials.

SSST = Sum of Squares, Subjects by Trials.

SSG = Sum of Squares for Groups.

SSC = Sum of Squares for Cells.

SSGT = Sum of Squares, Groups by Trials.

CT = Correction Term.

N = total number of observations. (76)

DF = Degrees of Freedom.

a = number of Groups. (2)

b = number of Trials. (2)

ne₁ = number of subjects, experimental group, before. (18)

ne₂ = number of subjects, experimental group, after. (18)

nc₁ = number of subjects, control group, before. (20)

nc₂ = number of subjects, control group, after. (20)

n = number of subjects. (38)

1. The Total Sum of Squares was calculated according to the following formulae:

$$CT = \frac{(\sum G + H + I + J)^2}{N}$$

$$TSS = (\sum K + L + M + P) - CT$$

$$CT = \frac{(\sum 35.15 + 36.80 + 38.72 + 36.14)^2}{76}$$

$$= \frac{21553.1761}{76} = 283.5944$$

$$TSS = (\sum 70.7475 + 70.1350 + 86.0034 + 69.0536) - 283.5944$$

$$= 295.9395 - 283.5944$$

$$= 12.3451$$

2. The Subject Sum of Squares was calculated according to the following formula:

$$SSS = \frac{Q + R}{2} - CT$$

$$SSS = \frac{311.7419 + 276.8536 - 283.5944}{2}$$

$$= \frac{588.5955}{2} - 283.5944$$

$$= 294.2977 - 283.5944 = 10.7033$$

3. The Sum of Squares for Trials was calculated according to the following formula:

$$SST = \frac{(G + H)^2}{ne_1 + nc_1} + \frac{(I + J)^2}{ne_2 + nc_2} - CT$$

$$SST = \frac{(35.15 + 36.80)^2}{18 + 20} + \frac{(38.72 + 36.14)^2}{18 + 20}$$

$$- CT = \frac{5176.8025}{38} + \frac{5604.0196}{38} - 283.5944$$

$$= .1114$$

4. The Sum of Squares, Subjects by Trials was calculated according to the following formula:

$$SSST = TSS - SSS - SST$$

$$SSSR = 12.3451 - 10.7033 - .114$$

$$= 1.5304$$

5. The Sum of Squares for Groups was calculated according to the following formula:

$$SSG = \frac{(G + I)^2}{ne_1 + ne_2} + \frac{(H + J)^2}{nc_1 + nc_2} - CT$$

$$SSG = \frac{(35.15 + 38.72)^2}{36} + \frac{(36.80 + 36.14)^2}{40} - CT$$

$$= 151.5771 + 133.0060 - 283.5944$$

$$= .9887$$

6. Error a was calculated according to the following formula:

$$\text{Error a} = SSS - SSG$$

$$\text{Error a} = 10.7033 - .9887 = 9.7146$$

7. The Sum of Squares for Cells was calculated according to the following formula:

$$SSC = \left(\frac{G^2}{ne_1} + \frac{H^2}{nc_1} + \frac{I^2}{ne_2} + \frac{J^2}{nc_2} \right) - CT$$

$$SSC = \left(\frac{35.15^2}{18} + \frac{36.80^2}{20} + \frac{38.72^2}{18} + \frac{36.14^2}{20} \right) - CT$$

$$= 68.6401 + 67.7120 + 83.2910 + 65.3049$$

$$- 283.5944 = 284.9480 - 283.5944$$

$$= 1.3536$$

8. The Sum of Squares, Groups by Trials was calculated according to the following formula:

$$SSGT = SSC - SSG - SST$$

$$SSGT = 1.3536 - .9887 - .114 = .2535$$

9. Error b was calculated according to the following formula:

$$\text{Error b} = \text{SSST} - \text{SSGT}$$

$$\text{Error b} = 1.5304 - .2535 = 1.2769$$

10. Degrees of Freedom were calculated according to the following formulae:

(a) Total Degrees of Freedom = $N-1$, or $76-1 = 75$

(b) Degrees of Freedom for Groups = $a-1$, or $2-1 = 1$

(c) Degrees of Freedom for Trials = $b-1$, or $2-1 = 1$

(d) Degrees of Freedom for error a = $(n-1) - (a-1)$ or $(38-1) - (2-1) = 37-1 = 36$

(e) Degrees of Freedom for Groups X Trials = $(a-1)(b-1)$ or $(2-1)(2-1) = (1)(1) = 1$

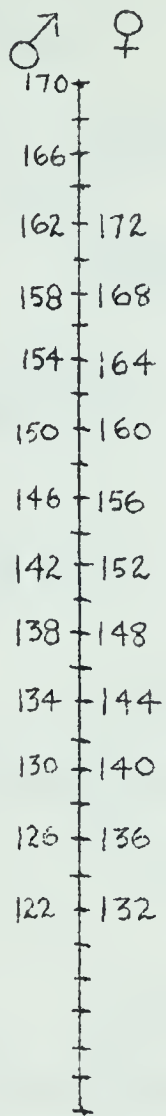
(f) Degrees of Freedom for error b = $(n-1) - (b-1)$ = $(38-1) - (2-1) = 37-1 = 36$

11. Appropriate Sums of Squares and Degrees of Freedom were then entered in the analysis of variance table (table V) and degrees of freedom divided into the sum of squares corresponding to get mean squares. Error a mean square divided into the Groups mean square gave the Groups F ratio. Error b mean square divided into Trials mean square gave the Trials F ratio and error b mean square divided into the Groups by Trials mean square gave the Groups by Trials F ratio. These ratios were entered into an F ratio Table with respective appropriate degrees of freedom to test for significance.

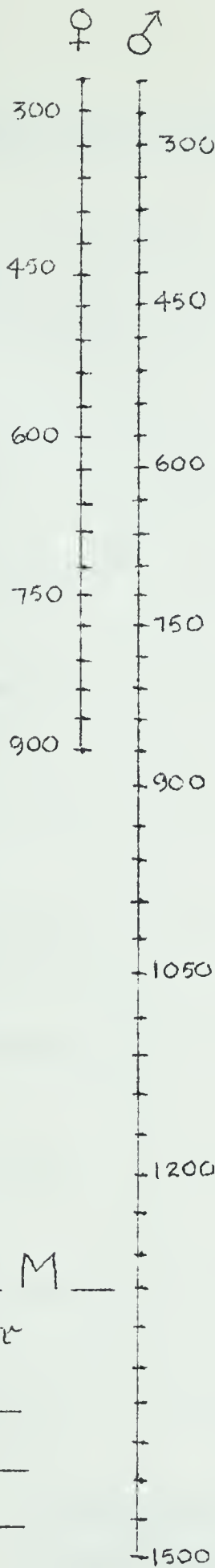
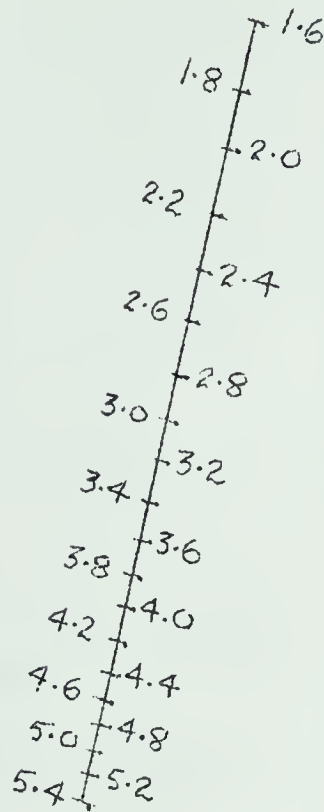
APPENDIX B
OXYGEN NOMOGRAM DATA SHEET
STRENGTH DATA SHEET

Code Number _____

Pulse



MVO_2



Work Load

MVO_2 _____ liters/minute

Name: _____ Sex _____

Pre Ex. Rate: _____ Age: Y _____ M _____

End of Min. Heart Rate Counter

1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____
5	_____	_____
6	_____	_____
7	_____	_____

Work Load _____

Steady State Pulse _____

Average R.P.M _____

Scale Setting _____

Strength Score Sheet

Name :

Code :
Pounds

	1	2	Best	
Grip / ^{Left}	_____	_____	_____	_____
Right	_____	_____	_____	_____

Back lift	_____	_____	_____	_____
-----------	-------	-------	-------	-------

leg lift	_____	_____	_____	_____
----------	-------	-------	-------	-------

^{Left}	_____	_____	_____	_____
Elbow Extension				
^{Right}	_____	_____	_____	_____

^{Left}	_____	_____	_____	_____
Elbow Flexion				
^{Right}	_____	_____	_____	_____

^{Left}	_____	_____	_____	_____
Knee Extension				
^{Right}	_____	_____	_____	_____

Summed
Strength
Score

APPENDIX C

RAW DATA

RAW SCORES OXYGEN CONSUMPTION AND SUMMED STRENGTH FOR BOYSEXPERIMENTAL BEFORE AND AFTER EXPERIMENT

Grade	Subject	Oxygen Value (L/min) Before	Oxygen Value (L/min) After	Summed Strength (lbs.) Before	Summed Strength (lbs.) After
8	1	2.60	2.68	1094	1228
8	2	1.90	1.81	903	1172
8	3	4.20	4.40	1390	1582
8	4	2.45	3.30	1124	1479
8	5	2.15	2.57	1042	1261
8	6	2.75	3.35	1249	1395
8	7	2.10	2.30	1180	1296
8	8	1.60	1.75	-	-
8	9	1.70	1.73	1259	1208
8	10	2.55	2.73	1059	1220
8	11	2.50	2.75	1048	1445
8	12	2.30	2.70	1382	1373
8	13	2.25	3.00	1441	1163
8	14	2.00	2.15	1086	1358
9	15	2.50	2.95	1347	1427
9	16	2.95	2.95	1756	1552
9	17	2.65	2.45	1600	1524
9	18	2.75	3.20	1471	2198
9	19	2.00	2.15	1532	1788
9	20	2.35	2.50	1568	1634
9	21	1.40	1.50	654	1042
9	22	1.70	1.75	1243	1628
9	23	2.00	1.90	1705	1736
9	24	2.35	2.25	1932	1780
9	25	2.25	2.10	2046	2236
9	26	2.80	2.85	1704	2060
9	27	3.60	3.60	1567	1951
9	28	2.60	2.93	1501	1832
9	29	3.20	3.53	1671	1725
9	30	2.65	2.45	1663	1836
9	31	2.25	2.25	817	1079

RAW SCORES OXYGEN CONSUMPTION AND SUMMED STRENGTH FOR BOYSCONTROL BEFORE AND AFTER EXPERIMENT

Grade	Subject	Oxygen Value (L/min) Before	Oxygen Value (L/min) After	Summed Strength (lbs.) Before	Summed Strength (lbs.) After
8	1	2.70	2.20	1555	1846
8	2	2.30	1.95	1070	1031
8	3	2.10	2.25	1176	1365
8	4	1.90	2.50	1025	1302
8	5	2.00	2.35	1098	1425
8	6	1.60	1.65	1690	1825
8	7	2.65	2.20	1670	1809
8	8	2.60	2.15	1469	1382
8	9	1.55	1.50	998	903
8	10	1.65	1.43	1042	690
8	11	2.90	2.65	1231	1151
8	12	2.80	2.70	1040	1244
8	13	2.00	1.75	1425	1580
8	14	2.40	2.51	1895	1737
8	15	1.30	1.33	1105	1184
9	16	2.15	2.15	1603	1610
9	17	3.40	2.41	1629	1629
9	18	2.10	2.25	1206	1235
9	19	2.65	2.73	1267	1599
9	20	2.30	2.50	1857	2297
9	21	2.70	2.90	1707	1928
9	22	2.30	2.40	1282	1383
9	23	2.55	2.75	996	1178
9	24	3.10	3.30	2083	2183
9	25	2.30	2.35	1254	1490
9	26	2.15	2.20	1610	1947
9	27	3.00	2.76	1847	1932
9	28	2.20	2.22	871	1234
9	29	2.80	3.40	1477	1769

RAW SCORES OXYGEN CONSUMPTION AND SUMMED STRENGTH FOR GIRLS

EXPERIMENTAL BEFORE AND AFTER EXPERIMENT

Grade	Subject	Oxygen Value (L/min) Before	Oxygen Value (L/min) After	Summed Strength (lbs.) Before	Summed Strength (lbs.) After
8	1	1.90	2.05	1028	1259
8	2	1.50	1.80	1176	1270
8	3	1.60	1.80	926	1445
8	4	1.40	1.85	933	1252
8	5	1.80	2.40	1084	1714
8	6	2.30	3.00	1197	1357
8	7	1.50	1.70	961	1100
8	8	2.20	2.76	943	1112
8	9	2.00	1.95	1244	1038
8	10	2.00	2.20	1280	1185
9	11	2.70	2.73	1203	1008
9	12	2.55	2.65	1217	1438
9	13	2.00	1.98	772	976
9	14	2.05	2.00	809	1191
9	15	1.90	2.10	1035	1250
9	16	2.20	2.15	1298	1523
9	17	1.80	1.60	1300	1407
9	18	1.75	2.00	676	911

RAW SCORES OXYGEN CONSUMPTION AND SUMMED STRENGTH FOR GIRLS
CONTROL BEFORE AND AFTER EXPERIMENT

Grade	Subject	Oxygen Value (L/min) Before	Oxygen Value (L/min) After	Summed Strength (lbs.) Before	Summed Strength (lbs.) After
8	1	1.90	1.25	1050	1230
8	2	1.40	1.40	1475	1352
8	3	1.45	1.55	698	874
8	4	1.40	1.30	941	1130
8	5	1.75	2.00	1126	1268
8	6	1.85	1.92	1358	1434
8	7	1.95	2.20	1201	1137
8	8	1.80	1.65	1363	1242
8	9	1.65	1.55	824	1045
8	10	1.75	1.58	1017	1148
8	11	2.35	1.82	1214	1233
9	12	1.60	2.05	1343	1177
9	13	2.65	2.78	1301	1172
9	14	2.30	2.30	959	1214
9	15	2.20	1.93	797	937
9	16	1.30	0.95	1136	1196
9	17	1.50	1.40	679	877
9	18	2.05	2.01	1233	1087
9	19	2.05	2.20	1230	1045
9	20	1.90	2.30	888	1151

APPENDIX D

CIRCUIT ADMINISTRATION

CIRCUIT ADMINISTRATION

Figure 5 shows the layout of the three circuits used in the experiment. All three circuits operated simultaneously, one-third of the class or about ten students performing on each. Students in each of these class sub-divisions would rotate through all three circuits over the course of three days, performing a different circuit each day in the three day cycle. The cycle would then be repeated.

Figure 6 is a diagrammatic presentation of the exercises in the regular and weight circuits. The third circuit, laps, needs no explanation.

Some features of the circuit which may be of interest are presented below. Letters and numbers in brackets refer to Figure 5.

1. Floor numbers (4) were painted on the gymnasium floor in three rows spaced to allow students to sit on their numbers in an arrangement which allowed all a view of the blackboard (3) and facilitated explanations and instructions on the part of the teacher.

2. Each student was assigned a floor number for the year and recorded circuits completed in the appropriate space by that same number on the moveable circuit recording board (2). Shelves were built under this board and numbered to allow each student to store his notebook on a shelf with the same number as his assigned floor number.

3. A twenty-four foot chinning bar (R1) was attached to the wall. It was constructed in three levels of graded heights ranging from about seven to nine feet from the floor.

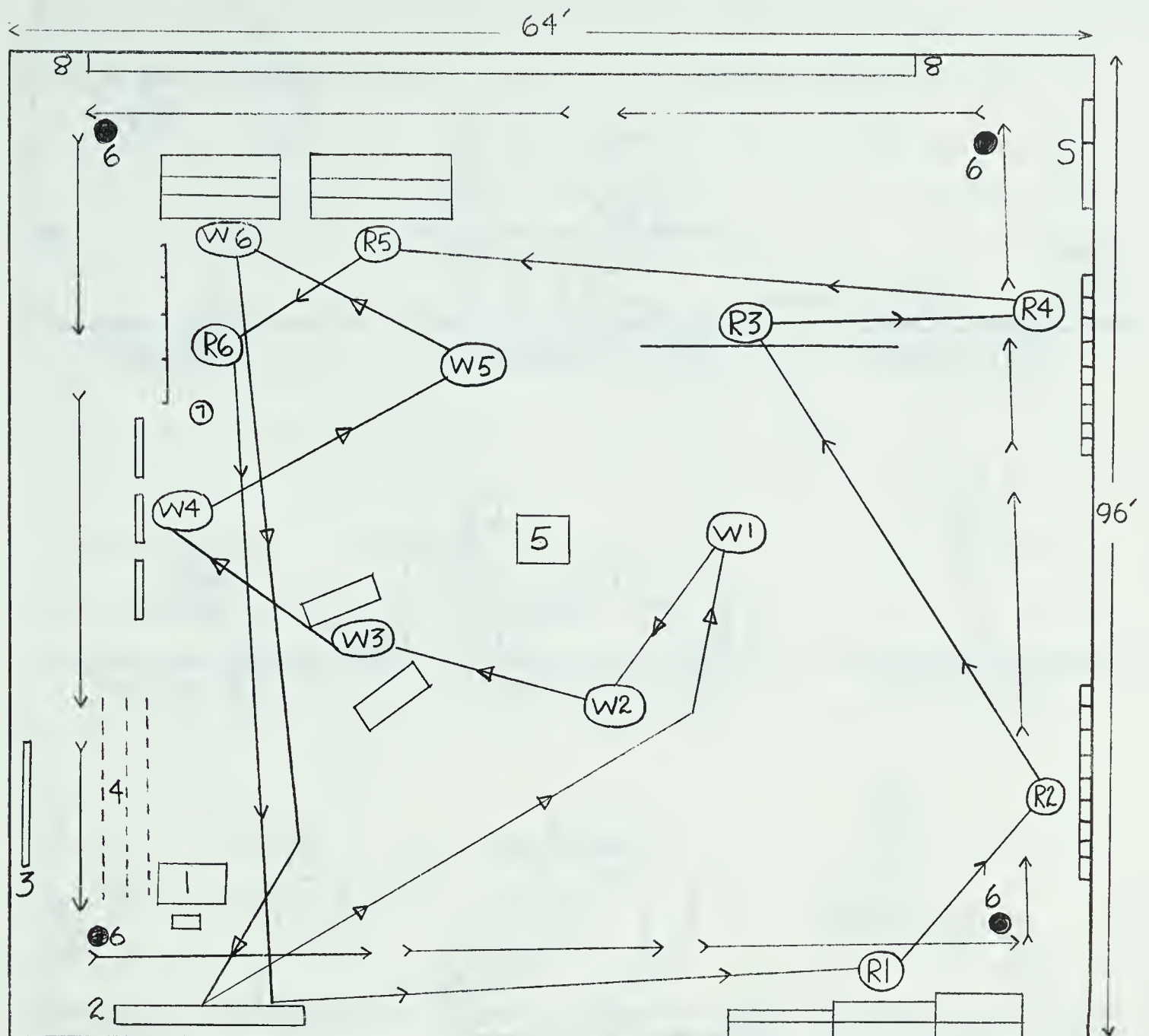


FIGURE 5.
CIRCUIT LAYOUTS

- | | | |
|---------------------------|--------------------------|------------------------|
| → Laps Circuit | 6 Circuit Monitor Stools | (R5) Bench Jump Bench |
| - - - Regular Circuit | 7 Skipping Rope Basket | (R6) Skipping Station |
| - ▴ - Weight Circuit | 8 Archery Backboards | (W1) Two Arm Curls |
| 1 Teacher's Desk | S Mallethorn | (W2) Dumbbell Swings |
| 2 Circuit Recording Board | (R1) Chinning Bar | (W3) Bench Presses |
| 3 Chalk Board | (R2) Knee Bend Hand Rail | (W4) Squats |
| 4 Student Floor Numbers | (R3) Push-ups Station | (W5) Two Arm Presses |
| 5 Weight Storage Cart | (R4) Sit-ups Foot Rail | (W6) Weight Bench Jump |

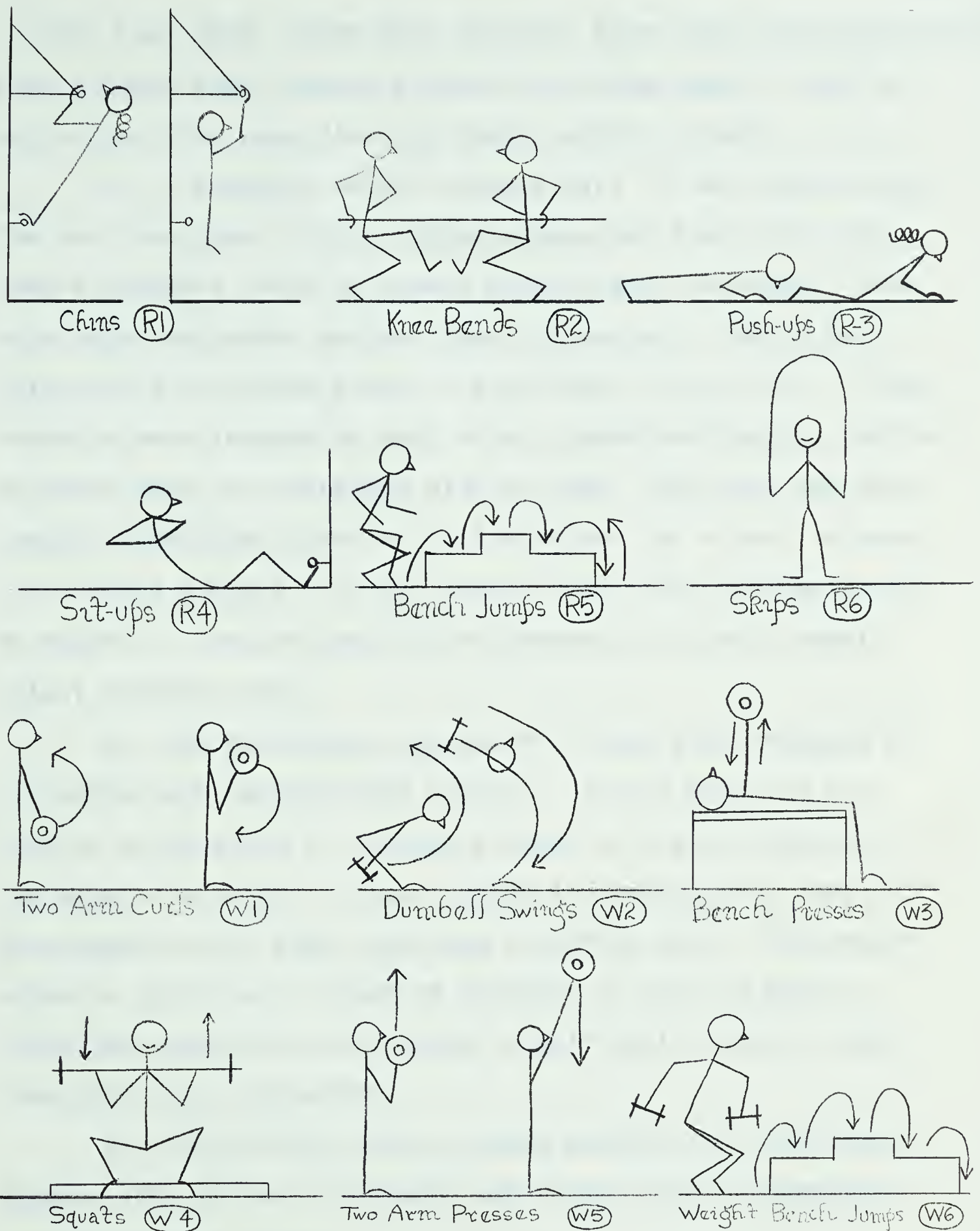


FIGURE 6.

CIRCUIT EXERCISES

Circled letters and numbers correspond to Figure 5.

A foot rest about three feet from the floor was also constructed. This allowed about twelve students of either sex to use the bar at one time regardless of their relative sizes.

4. A moveable weight storage cart (5) was constructed. The cart was about thirty inches square and four feet high. Twelve dumbbells could be stored horizontally, arranged three to a side, one above another near its center. Twelve barbells could be stored around the periphery of the cart. Three barbells were located on each side, stored vertically, resting on their ends, but arranged side by side. The cart was built locally under the direction of the writer for a cost of about two hundred dollars. It can handle about five hundred pounds of weights. The cart made it unnecessary to have a special weight training room.

5. The Matterhorn peg board (S) was also designed by the writer and manufactured locally. It was built in the form of an inverted V. Students began at one end, placing the pegs alternately in empty holes in the board as they progressed to the peak then down the other side. The design allows a continuous stream of students to use the device, those just beginning not having to wait until those on the "mountain" have descended.

6. The benches used in bench presses (W3) and bench jumping (W6, R5) were moveable and stored off the gymnasium floor playing surface.

7. The moveable teacher's desk and chair (1) allow the teacher an energy conserving station from which to monitor performance on the circuits.

8. Students who were excused from physical education for medical reasons were used as circuit monitors. They were located on stools (6) which also served as corner posts for the laps circuits.

9. Special ribbons marked Centennial Circuit Citation were awarded students judged by teacher and monitors to have done the circuits with the greatest enthusiasm, vigor and honesty in a given week.

10. With planning, about one minute was needed to take out the circuit equipment and about one minute was needed to re-store it.

11. To determine student work loads on the Regular Circuit a test was administered before the experiment and also after five weeks. The test consisted of doing the exercises required for each station for one minute. The rest period between stations increased from one through five minutes allowing an additional minutes rest with each station performed. In order to get maximum performance from students a "fitness" score was calculated (Appendix E). Students were paired for the Circuit Test, one being a recorder, the other the subject. The recorder would count the total number of repetitions done by the subject and enter under a column on the score sheet called "Possibles". While counting, the recorder would put a check mark down under a column marked "Check-offs" for each poorly performed repetition. The "check-offs" were subtracted from the "Possibles" and the resulting total entered in a column marked "Actuals". The "Possibles" tally was used in computing a student's circuit

dosage.. The circuit dosage for each station would be one-half the tally in the "Possibles" Column. However, only well performed exercises as tallied under the "Actuals" column went into calculating the fitness scores. The t effect was to get conscientious effort on the circuit test.

12. Students arranged the weight dosage by a self-administered test. They experimented with each of the three weights available for each station to see which one they could lift maximally between twelve to twenty-four times. Once having determined this, they used that weight at half their maximal repetition rate on each circuit.

APPENDIX E
CIRCUIT TEST SCORE SHEET

Circuit Test Score Sheet

Name of Subject _____ Name of Recorder _____

A Circuit Test Possibles - minus - Check Offs - equals - Actuals

Chins	_____	-	_____	=	_____
Knee Bands	_____	-	_____	=	_____
Push Ups	_____	-	_____	=	_____
Sit Ups	_____	-	_____	=	_____
Bench Jumps	_____	-	_____	=	_____
Skips	_____	-	_____	=	_____

B Circuit Scores



Chins	_____ ÷ 2 = _____
Knee Bands	_____ ÷ 2 = _____
Push Ups	_____ ÷ 2 = _____
Sit Ups	_____ ÷ 2 = _____
Bench Jumps	_____ ÷ 2 = _____
Skips	_____ ÷ 2 = _____

C Fitness Score

To Z



Boys X 2	_____	
Girls ÷ 3	_____	= _____
÷ 2	_____	= _____
Boys Same	_____	
Girls ÷ 2	_____	= _____
Same	_____	= _____
Same	_____	= _____
÷ 4	_____	= _____

Column Y is number of repetitions you will do each day on Regular Circuit. Round off halves to next whole number.

_____ ÷ 6 = _____

Total of Column W Fitness Score

Scale: Poor = 10-down, Fair = 11-15,

Average = 16-20, Good = 21-25,

Excellent = 26-30, Superb = 31-up.

D Weight Circuit

Find weight you can lift 12 times but not 24

Weight Numbers 1/2 Q max. Colour

Curls	<u>1</u>	<u>2</u>	<u>3</u>	_____	_____
Swings	<u>16</u>	<u>17</u>	<u>18</u>	_____	_____
Bench Prs.	<u>4</u>	<u>5</u>	<u>6</u>	_____	_____

Weight Numbers 9 Q Colour

Squats	<u>7</u>	<u>8</u>	<u>9</u>	_____	_____
Presses	<u>10</u>	<u>11</u>	<u>12</u>	_____	_____
Ben. Jumps	<u>13</u>	<u>14</u>	<u>15</u>	_____	_____

Column Q is one-half the 12-24 rate --- this is done each day on the Weight Circuit Round off halves to next whole number.

B29865